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TECHNICAL REPORT 88-03

OBERBAUENSTOCK (OBS) 1987:

RESULTS OF THE HYDROGEOLOGICAL TESTING PROGRAM OBS-1

K.G. KENNEDY
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FEBRUARY 1989

Gartner Lee Limited
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ABSTRACT

In order to determine the hydrogeological characteristics of the rock mass at the potential repository site for low and medium level radioactive waste at Oberbauenstock, a total of 30 hydraulic packer tests were conducted in 1987 in the three boreholes drilled.

This report contains technical information on testing activities as well as the results of the first stage of analyses done in the field. The first part emphasizes information on the testing methodology and on the equipment used. The methods for test analysis are described and illustrated by means of three selected test examples. In one chapter special tests dedicated to the investigation of system's compliance effects are described. The results of the tests done are contained in the last part of the report. The text is supplemented by a number of figures and tables. In addition, test data and results for all individual tests performed are compiled in the appendix.

ZUSAMMENFASSUNG

Im Rahmen des 1987 abgewickelten Felduntersuchungsprogramms der Nagra am potentiellen Endlagerstandort Oberbauenstock für schwach und mittelaktive Abfälle wurden in den drei abgeteuften Bohrungen insgesamt 30 Packertests zur Bestimmung der hydraulischen Parameter des Gebirges durchgeführt.

Der vorliegende Auftragnehmerbericht fasst die Testarbeiten und die Ergebnisse der Feldauswertungen zusammen. Im ersten Teil sind ausführliche Angaben zur Testmethodik, namentlich zu den verwendeten Ausrüstungen und zu den Testverfahren enthalten. Die Analysenmethoden für die Tests werden beschrieben und anhand von drei ausgewählten Testbeispielen dargelegt. Ein Kapitel ist der Durchführung spezieller Tests zur Abklärung des Verformungsverhaltens der verwendeten Packer gewidmet. Die Ergebnisse der durchgeführten Tests sind zusammenfassend im letzten Berichtsteil dargestellt. Zahlreiche Figuren und Tabellen ergänzen den Text. Zusätzlich sind für alle durchgeführten Einzeltests im Anhang Daten und Resultate mit den zugehörigen Figuren enthalten.

RESUME

Dans le cadre du programme d'études de terrain réalisé par la Cédra en 1987 sur le site potentiel pour déchets de faible et moyenne activité d'Oberbauenstock, trois forages ont été exécutés. Dans ces derniers, un total de 30 essais par obturateurs (packers) a été réalisé afin d'étudier les paramètres hydrauliques de la roche.

Le présent rapport résume les essais réalisés et les résultats de l'interprétation de terrain des mesures. Dans la première partie, la méthodologie des essais est présentée de manière détaillée; les équipements utilisés et le processus des mesures sont commentés. La méthode d'analyse des essais est décrite et expliquée au moyen de trois exemples choisis. Un chapitre est consacré à la réalisation d'essais spéciaux destinés à déterminer la déformation des obturateurs utilisés. Les résultats des mesures sont présentés de manière résumée dans la dernière partie du rapport. De nombreuses figures et tabelles illustrent le texte. D'autre part, les données et les résultats de chacun des essais ainsi que les figures correspondantes sont présentés en appendice.

SUMMARY

In the course of a first phase of site investigations named OBS-1, the Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (Nagra) carried out a drilling and testing campaign in 1987 at the potential repository site for low and medium level radioactive waste at Oberbauenstock. The general objective was to determine the geological, petrophysical and hydrogeological characteritstics of the host rock, the so-called 'Valanginian' marl, which is overlying limestones and shale formations.

Drilling and testing activities were done in an existing gallery, which is an auxiliary structure of the Seelisberg Road Tunnel. The rock overburden in the tunnel area used as a drill site is several hundred meters. The region has a surface relief ranging from about 500 to 2700 m asl.

Due to the small available space, access restrictions and the presence of methane gas in the host rock the investigations necessitated highly coordinated logistics and special equipment to work efficiently and to meet safety requirements. All boreholes were equipped with blow-out preventers. This further limited access and equipment flexibility at the wellhead.

Hydrogeological investigations consisted essentially in hydraulic packer testing. Testing emphasis was on the more permeable discontinuities found in the Valanginian marls and the underlying limestone. A total of 30 tests were conducted in the three boreholes drilled.

Two shallow boreholes, HVB (vertical) and HGB (45° inclined), were drilled to the total depth of 100 m at a borehole diameter of 96 mm, using only fresh water as a drilling fluid. Following drilling, screening tests were made over packed-off intervals of about 20 m length in each borehole. Results from the screening tests and available borehole geophysical and geologic information were then used to determine the zones for detailed testig with reduced 5 to 6 m straddle length.

The third borehole, SA, was drilled and tested in several stages. Its total depth was 350 m. Drilling was interrupted to test opposite two zones at depths of about 100 and 160 m when drilling fluid losses on the order of hundreds of litres occurred. Borehole sloughing occurred opposite one zone at a depth of about 240 - 260 m. This required the testing equipment to be lowered

and raised through the drill pipe to access the two deepest zones tested at about 300 and 310 m. The downhole hydraulic testing assembly consisted of an oil field-type single packer or double straddle packer system. Inflation was controlled from the surface using a constant pressure nitrogen gas source connected to the packers through a water-filled inflation line in an encapsulated bundle. The bundle also contained a second hydraulic line accessing either the zone between or below the packers, and a single conductor wireline that transmitted pressure and temperature sensor frequencies from the downhole sensors to the surface computerized data-acquisition system. Pressures were continuously measured in the zones above, below, and between the packers during testing. This permitted online surface monitoring of in situ transient conditions as testing occurred. The downhole sensor data were processed using a 32-bit cpu operating Unix-based data acquisition and test analysis software. The multi-tasking capability of this system permitted analysis in real time as well as on-screen comparison of model simulation results concurrent with data acquisition.

Testing methods included typical single-well tests such as pulse, slug, drill stem-type, constant head and/or flow-rate injection tests. Two compliance tests were also performed in casing to evaluate the system response and observe any effect of pressure changes in the intervals and the packers. One of the more permeable zones that had been tested with water was also tested using injected nitrogen gas. The purpose of this gas test was to evaluate the mobility of water in the formation in the presence of gas at higher pressures.

Field and follow-up analyses were done for all intervals tested. Field analyses were based on standard porous media assumptions, using simplified type-curve matching and straight-line approximation techniques. Follow-up analysis involved the use of a numerical wellbore simulation model, GLIMPSE. It was used to 'bound' the test data. The model included wellbore storage for the interval volume, and assumed formation conditions were homogeneous, isotropic with radial flow into the test interval. An important aspect of using this method of analysis was the ability to assess the effect of borehole pressure history. This was important for estimating the true in situ pressure of the rock compared to the overpressures imposed from borhole history activities prior to and during testing. No skin effect or fracture flow analysis were incorporated at this stage of analysis.

Hydraulic conductivity values of the Valanginian marls and limestones tested ranged from less than 1E-13 m/s to about 1E-8 m/s. A section of the unfractured matrix rock was tested and values of less than 1E-13 m/s were obtained. Test intervals containing discontinuities had the higher values of permeability. Good correlation was obtained between the results of the screening tests and the subsequent detailed tests in the interval. Comparable results were obtained in the zone which was tested using both water and gas. No apparent trend in hydraulic conductivity versus depth was evident at any of the boreholes. Skin effects were observed during testing in some of the intervals. No accurate values of storativity could be determined. A three order of magnitude range was generally used in the bounding approach. In some instances, the presence of a gas phase was indicated by observed high wellbore storage conditions.

The hydraulic head values for all test zones were unexpectedly below the level of the tunnel floor. The ten intervals tested in the HVB borehole exhibited relatively low permeability, and no representative formation pressure values could be determined at this stage. Representative pressures could be determined in several of the more permeable zones tested in the HGB and SA boreholes. Hydraulic head values calculated from these pressures indicated the elevation varied from about 20 m below the tunnel floor to as much as 80 m below the level of the nearby Lake Uri. The anomalously low pressures may be related to degassing of existing or former pockets of gas within the marls and claystones.

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1. INTRODUCTION

This report presents the work done at the Oberbauenstock site for Nationale Genossenschaft fuer die Lagerung radioaktiver Abfaelle (NAGRA) in the course of the Phase 1 field investigations in 1987, called OBS-1.

The report is organized in the following Sections:

ABSTRACT
1. INTRODUCTION
2. OBERBAUENSTOCK SITE
3. FIELD TESTING METHODS
4. INTERPRETATION METHODS AND REPORTING
5. CASING TESTS
6. TESTING AND INTERPRETATION EXAMPLES
7. RESULTS OF HVB
8. RESULTS OF HBG
9. RESULTS OF SA
10. REFERENCES

Section 1 describes the background, objectives, scope, schedule and management aspects for the project. Section 2 describes the setting and environment of the site. Section 3 outlines the equipment and testing methods used. Section 4 outlines the analysis methods used at the different stages of reporting. Section 5 discusses the results of measurements made in casing both in and outside the borehole to evaluate the compliance of the downhole testing equipment. Section 6 presents the results from three intervals which illustrate the typical testing methods and analysis approach. Sections 7, 8, and 9 present the results of the testing done in the three different boreholes HVB, HGB, SA drilled at Oberbauenstock. Section 10 lists the references cited in the report.

Technical specifications and testing methods for the project were defined by NAGRA. This was done originally in Nagra's working program document, NTB 87-04, and subsequently in association with the actual testing program. The performance requirements were kept flexible to allow the technical approach to be tailored to the site specific conditions that were encountered during the work program.

1.1 Background

The basic concept of the Oberbauenstock repository project is to store the radioactive waste in a horizontally accessed cavern system located at depth in geological units of low permeability.

Site investigations consist of two phases:

Phase I - preliminary investigations to improve the basis of decision with respect to the possible excavation of an investigation gallery.

Phase II - excavation of an investigation gallery and execution of related detailed investigations.

The investigations including hydraulic testing and ground water sampling presented in this report belong to Phase I (OBS-1). They were carried out at the Oberbauenstock site (Figures 1.1, 1.2) in the summer of 1987.

1.2 Objectives

The objectives of the hydraulic testing and ground water sampling program carried out at Oberbauenstock were defined by NAGRA (NTB 87-04) as:

1) Determination of hydraulic conductivity of rock and of singular discontinuities within the host rock taking into account the following media within the host rock (Valanginian marl):

   - shear zones
   - marly limestone layers
   - rock mass in the area of approx. 20 m borehole sections
   - undisturbed rock - "matrix"

2) Determination of the hydraulic conductivity of the underlying formations (Valanginian limestone and/or Tertiary shales).

3) Determination of hydraulic pressure (environmental head) in the host rock and in the underlying formations.

4) Sampling of ground water from the host rock and the underlying formation in the boreholes for chemical, isotope and gas analysis.

1.3 Scope

Three boreholes were cored, geophysically logged and hydraulically tested at Oberbauenstock during the Phase 1 site investigation (Figure 1.3). Table 1.1 summarizes the borehole specifications and hydraulic testing and sampling activity conducted at the site.

The three boreholes were:

HVB - a shallow vertical boring about 100 m deep for hydraulic parameter determination.

HGB - a shallow inclined boring 100 m long for hydraulic parameter determination.

SA - an intermediate depth vertical boring for geometry and hydraulic parameter determination.

The OBS-1 program involved several activities which included hydraulic testing. The general sequence of the OBS-1 activities was:

1) drill HVB, log, test, and leave it open in the event that the option to deepen the boring is selected.

2) drill HGB, log, test and cement it.

3) move rig, drill SA, log, test, log and cement it.

4) move rig back to HVB, log and cement it.

Drilling of all boreholes was done without the use of additives. Natural materials in the rock being cored formed suspended materials in the drilling fluid. Periodic circulation was done to replace the fluid with fresh water. The water used for drilling was taken from nearby Lake Uri.

Testing and sampling activities were done in the HVB and HGB boreholes after drilling and geophysical logging had been completed to total depth. Testing began with screening tests of about 20 m length which covered most of the borehole. Screening tests results were used to determine the zones that were investigated in detail with shorter interval lengths.

Testing and sampling activities in the SA borehole weredone as drilling progressed as well as after it had been drilled to total depth. Interval lengths varied as did the length of time associated with the testing in each zone.

Summaries of the HVB, HGB and SA interval activities and analysis approach are in Appendices A, B, and C, respectively.

Two tests in casing were also conducted. The first was done downhole in the HVB borehole casing. The purpose of this first test was to observe the influence of changing packer inflation on the interval pressure. The second was done in a subhorizontal pipe at the surface near the entrance of the access tunnel. The purpose of this second casing test was to investigate the compliance of the packer system. Results from the casing tests are discussed in Chapter 5.

Reporting was continuous from the start of testing until the end of November, 1987. Details of reporting are in Chapter 4. Copies of all interval testing data generated during the program were copied from the original format, modified and set up as ASCII files. The data was copied onto 5 1/4-inch floppy disks and sent to NAGRA for subsequent in-house use.

1.4 Schedule

NAGRA issued the tender documents in July, 1986. Bid packages were submitted in September, 1986. Interviews with selected bidders were held in NAGRA's offices in Baden later that month. In December, 1986, NAGRA authorized GLAG to begin preparation work. Preparations continued until mobilization.

Heavy equipment was shipped from USA, Canada, and Germany near the beginning of May, 1987. Move-in and set-up of drilling and other heavy equipment in the gallery began on May 8. Staff and support equipment arrived at the site in the middle of May. Drilling of the HVB borehole began on May 18. A two-day technical seminar on the planned OBS-1 hydraulic testing was held in Baden on May 18 and 19.

All required staff and equipment were at the site on May 21. The testing equipment was set-up for testing by May 25. Figure 1.4 illustrates the activities that took place during the 98 day period of performance for the testing and sampling at the site. The HVB testing began on May 27 and lasted until June 9. Testing in HGB began on June 19 and lasted until July 3. Drilling of SA began on July 6 and the first testing began on July 16. Drilling with intermittent testing continued until August 01. Final SA testing began on August 7 and lasted until August 24.

Technical reports with the results of testing were generated both during testing and after demobilization. The final individual interval reporting was complete at the end of November, about 3 months after completion of the testing.

1.5 Project Management and Infrastructure

NAGRA was responsible for coordination, safety, and scheduling of site activities. NAGRA specified the borehole depths to be tested, the manner in which the testing was to be done, and the amount of time allocated to each interval.

GLAG acted as the Technical Services Management Contractor (TSMC) for the hydraulic testing and water sampling work.

GLAG contracted with Baker Production Technology/Lynes GmbH (BPT/Lynes) in the Federal Republic of Germany and the Whiteshell Nuclear Research Establishment of the Atomic Energy of Canada, Limited (WNRE/AECL) to provide technicians and equipment to assist with the work. BPT/Lynes was responsible for supplying staff and their downhole testing equipment. WNRE/AECL provided direction and support for the downhole shut-in tool and some of the ground water sampling equipment.

1.6 Acknowledgements

GLAG acknowledges the cooperation and assistance of the following organizations and their staff during the preparation and on-site work: BPT/Lynes, FRG; BPT, Houston; Geologisches Buero Schneider, CH; Danzas, FRG and CH; G-Tech Corp., Houston, GEMAG, CH; Gewerkschaft Walter GmbH, Essen, FRG; Micromotion, Inc. USA; NAGRA, CH; SOLEXPERTS, CH; Technical University of Claustal-Zellerfeld; and, WNRE/AECL, CAN.

Particular thanks are extended to Dr. T. Kuepfer, Dr. R. Andrews and Dr. P. Hufschmied of NAGRA. Their management and technical guidance through the program contributed to its success.

2. OBERBAUENSTOCK SITE

The purpose of this section is to describe the physiography and hydrogeologic setting of the site.

2.1 Physiography of Site and Location of Borings

The site is located in the Canton of Uri, in the central part of Switzerland, close to the west shore of Lake Uri in the vicinity of the Seelisburg tunnel (Figure 1.2). The area has a rugged relief typical of an alpine setting. Lake Uri is the deepest main drainage in the region. It has an elevation of about 433 m. The nearby peaks of both Oberbauenstock and Niederbauen are at elevations of 2117 and 1923 m, respectively.

The tunnel area where the boreholes are located is about 800 m from the edge of Lake Uri and at an elevation of about 490 m. The rock and overburden thickness above the drilling gallery is about 500 m and the land surface elevation immediately above the drilling sites is about 1000 m.

2.2 Hydrogeologic Setting

The geological and hydrogeological setting of the site has been described previously (NAGRA NTB 84-20). The area is mountainous. The drilling gallery was below the local water table, but above the regional drainage level when construction began. The impact of the Seelisburg tunnel and the ventilation and access galley structures on the water table has not been determined. In general, however, it is expected that both these structures will have caused localized cones of depression around the tunnels that could extend for considerable distance away from the site area.

The host rock consists of marls of Valanginian age with variable clay and carbonate contents, laminated, overprinted by alpine tectonics and very low grade metamorphism. The underlying rock is Valanginian limestone and Tertiary sandstones and shales.

Local discontinuities occur in the entire series of rocks. Fault lineaments and scarps are visible in both plan and cross-sectional landscape perspectives.

The original flow system concept was that the Valanginian marls were made up of extensive thicknesses of matrix rock with rare, but significant discontinuities in which most of the fluid movement was expected to occur. A system consisting of two shear zones and one bedding plane system was believed to be associated with the region.

Investigations from the OBS-1 program have indicated that this generalization is true. Detailed study of the geology of the project cores as well as geophysical work have indicated that the folding and faulting in the site vicinity are rather complex. Flow pathways are definitely outside the rock matrix.

There is more hydraulic isolation of the discontinuities from surrounding local water features than had been expected. Hydraulic heads range from above the level of Lake Uri to depths of one hundred meters below lake level.

Gas of mainly methane composition was detected in pockets during the construction of the Seelisburg tunnel particularly in the Valanginian marl rocks. An active methane source is still venting within about 20 m of the SA borehole. It appears that the porous reservoirs originally containing the methane gas have been or are in the continued process of being depleted. The impact of this degassing on the local flow system in the site vicinity is not well documented nor clearly understood at this time. However, the presence of depleted former gas reservoirs as pockets or lenses in the relatively tight marls could account for the low pressures documented in the SA borehole (Chapter 9).

The sequence of drilling and testing of the boreholes was presented in Chapter 1. Figures 2.1 through 2.3 illustrate the sections and the sequence of testing in the HVB, HGB and SA boreholes, respectively.

3. FIELD TESTING METHODS

The purpose of this section is to describe the equipment and testing methods that were used to perform the hydraulic testing and water sampling. Much of the equipment and testing methods used at Oberbauenstock have been previously used on the northern Switzerland deep drilling program, and have been reported upon in several NAGRA Technical Reports (NTB's)(NTB 85-8, NTB 85-9) and unpublished internal documents (NIB's). The emphasis in this section is, therefore, on the new aspects of the equipment and testing approaches. The sedimentary rock environment and limited working space at Oberbauenstock required that modifications be made to both these aspects in order that the work could be done more efficiently yet with a sound technical approach.

3.1 Equipment

The downhole and surface testing equipment used in this project was developed specifically to be used in underground settings with access and size restrictions, and with explosion-proof operational requirements. At the same time, the equipment had the high-durability and performance standards that had been demonstrated on the northern Switzerland program. Most equipment performed as expected and met the project specifications.

The description of the testing equipment is presented from the bottom of the borehole up to the surface data acquisition system. The equipment description is according to the following categories:

- Hydrogeologic Testing Equipment
- Water Sampling Equipment
- Data Processing Equipment

3.1.1 Hydrogeologic testing equipment

The basic components that make up this equipment as shown schematically in Figures 3.1 and 3.2 are:

- Packer assembly
- Tubing string
- Swabbing equipment
- Surface pressure measurement system
- Flow measurement and control system

3.1.1.1 Packer assembly

The five principal components of the packer testing assembly as shown in Figure 3.2 are:

- packers,
- encapsulated bundle,
- pressure/temperature sensors,
- flow housing, and,
- downhole shut-in valve.

BPT/Lynes of Celle (FRG) provided the first four equipment items listed above. WNRE/AECL provided the downhole shut-in valve.

Fluid flow pathways through the tool are both small and tortuous. The openings can cause non-laminar flow conditions at rates in excess of about 4 litres per minute of water. Figure 3.3 contains a summary of the pressure drops that were documented to have occurred during pre-testing of the tool done by its manufacturer (see NIB 88-05 for details). For relatively low permeability testing environments such as that encountered at Oberbauenstock, this rate of water flow is not often encountered. Therefore, this tool flow condition did not influence the testing conditions for the project.

Packers

Inflatable packers isolated each section or interval from the rest of the borehole when testing. Both single and double (straddle) configurations were used. High strength, metal braided, rubber elements were adapted from products used in the petroleum industry. Modifications allowed packer inflation from the surface, a change from typical and past procedures.

Packer inflation procedures can influence interval pressure both at the beginning and during testing. Both the packers and the inflation line were filled with water prior to testing. Pressurizing the packers was done in two steps. First, a small compressor pump was used to increase the inflation line pressure to about 50 bars. Second, the line was connected to a nitrogen gas cylinder to maintain the pressure. An in-line transfer vessel with a liquid-level site glass was filled with water to keep the inflation line full of water and reduce the volume of nitrogen gas used. This procedure maintained constant pressure on the inflation line, at least to the nearest bar. The four HVB screening tests were done prior to this equipment being set up at the site. For these tests, the inflation line surface valve was closed at the surface after initial inflation and the pressure decreased with time due to continued packer inflation and deformation.

Inflation pressure was continuously monitored as described in Section 3.1.1.4.

Encapsulated bundle

An encapsulated bundle was lowered along with the packer assembly, strapped to the side of the tubing string. The bundle size of 13 mm by 30 mm contained two hydraulic lines and one electric line as follows:

- a stainless steel line to inflate the packers,
- a stainless steel line to provide various downhole porting options to the surface, and
- a single conductor wireline cable to transmit the downhole pressure and temperature sensor data to surface.

The encapsulated line was manufactured using an extrusion process which uniformly surrounded continuous lengths of the three lines with a semi-rigid material. This technique provided a highly durable, yet flexible umbilical-type configuration. Up to 500 m was stored and operated from a 1 m diameter cable reel.

Pressure/temperature sensors

Monitoring and transmission of pressures from above, between and below the packer assembly in real time is an important feature of the testing equipment. The BPT/Lynes Triple Continuous Wire Line (TCWL) electronics unit contains three quartz transducers with coupled thermistors (Figure 3.4). The three pressure transducers port directly to the three zones of interest and, therefore, reflect the pressures in those zones. The pressures, however, represent measurements at the transducer depths and need to be extrapolated for bottomhole or interval midpoint values. By convention, annulus, interval and bottomhole pressures are designated as P3, P2, and P1 pressures, respectively.

A single packer configuration results in both the P1 and P2 transducers monitoring the interval pressure below the only packer. However, the two pressure values are not equal due to the difference in porting in the channels from the interval to the sensor carrier, and the potential for air to occur in the lines between the interval and the sensor carrier.

The three thermistors are attached directly at the sensor and the values are recorded at that depth and location. As such, the thermistor temperatures represent the value at the sensor depth rather than for the midpoint of the interval. Erratic fluctuations can occur when tool movements are made to change testing activities. In general, however, the responses are more gradual and represent the environmental conditions in the vicinity of the sensor carrier. When there is fluid flowing into or from the interval, there may be associated changes depending on the temperature of the fluid flowing past the sensors compared to the ambient temperature at the sensor depth.

The pressure and temperature sensors are calibrated so that a specific frequency relates to a given data value. Calibration of the TCWL is done at BPT service headquarters in Houston, Texas. The calibration consists of a series of step-wise pressure and temperature increases using a high-accuracy dead-weight tester in an oven. Calibration data result in a series of pressure and temperature coefficients that are entered into the data acquisition software.

The frequency data are electronically multiplexed from the six sensors and a time stamp is added. In the Oberbauenstock testing program, the time stamp assigned was the mean time for the interval pressure reading. A single cycle of all pressure and temperature readings is transmitted as frequently as every 6 to 7 seconds as shown on Figure 3.5. Specifications for the sensor assembly are given in Table 3.1.

<u>Flow housing</u>

The flow housing was added to the tool specifically for this testing at Oberbauenstock. The housing allows changes in the porting configuration of the downhole assembly. The practical options are:

- the annulus equalized with the bottomhole zone,
- a hydraulic connection between the surface and the interval,
- a hydraulic connection between the surface and the bottomhole zone, and,
- the single packer assembly to have the P1 and/or P2 transducer monitoring the interval pressure.

NAGRA's original specifications and test plan called for the ability to have the zone below the bottom packer pressure-equalized with the annulus. However, this configuration was never used. Instead, the testing in both 100 m boreholes was done with the bottomhole zone ported to the surface. It was hoped that this porting would allow testing of both the interval and the bottomhole zone with the same straddle setting and thus reduce the number of times the packers needed to be reset.

The fluid levels in all borehole intervals were below the tunnel floor. This resulted in erratic P1 pressure behaviour when the P1 line was closed at surface and the fall-off exceeded 10 m. Water vapour pressures formed in some of these cases and the P1 pressure was drawn down below atmospheric conditions. In addition, the P1 line to surface had been initially been filled with water. The suction effect of the fluid level in the bottomhole zone resulted in cyclic fluctuations in the P1 pressure as the fluid level in the cable reel rose and fell as it was being emptied.

Shut-in valve

Reducing the shut-in volume in the interval reduces the response time for an event back to static conditions and, influences the distance away from the borehole all that is tested during an event. Therefore, the use of a downhole shut-in valve gives a high degree of flexibility to a testing program.

The typical oil industry shut-in valves are operated mechanically and require either tubing string rotation or an up/down movement. Rotation was not practical with this equipment because the encapsulated bundle was strapped to the side of the tubing string. The up/down movement has historically caused unpredictable, irregular pressures as the result of unmeasured volume displacements occurring at the beginning and end of some events.

The shut-in valve used at Oberbauenstock was electronically activated from the surface and had no measurable volume displacement when activated. The WNRE/AECL Fast Acting Valve (FAV) allowed the interval to be shut-in from, or opened to, the tubing string fluid level in microseconds. There was neither volume displacement nor movement of the tubing string resulting from the operation of the valve. The non-displacement feature was technically advantageous. Better control of the initial pressure conditions for pulse tests was obtained.

Perhaps more important was that the electronic activation was highly cost-effective. The tool could be opened and closed with only one on-site person. Previous testing required both a drill crew and packer technician present, as well as the supervising hydrogeologist.

The disadvantage to the valve was that it required an additional cable to be run down along side the tubing string. The more cables in the hole, the higher the damage risk, particularly in narrow boreholes such as the 96 mm diameter ones drilled at Oberbauenstock. There were no damaged cables on the trips in and out of the three boreholes. However, on future programs, this cable would likely be included with the more durable encapsulated bundle, virtually eliminating this risk.

3.1.1.2 Tubing string

The downhole packer assembly was lowered into the boreholes on tubing string. The tubing string selected was manufactured by Mannesmann-Tally, FRG. The type of tubing was 1.90-inch, non-upset, 41 mm ID, N-80 grade steel with API 10-round threads. Its rated pulling capacity exceeded that of the drilling rig.

The tubing was threaded and cut to NAGRA's specifications for the OBS-1 tunnel environment. The tubing needed to be cut in relatively short lengths for use in the restricted underground space. Lengths were nominally 1.5 m and 3 m. Each joint of tubing was stamped with a unique identification number to ease preparing and verifying the tubing tally for each interval depth. The use of threaded protective end caps and inserts on each joint reduced damage.

3.1.1.3 Swabbing equipment

Removing fluid from the tubing string was done to conduct slug withdrawal tests, for clean-up and for sampling. Conventional wireline-type swabbing equipment could not be used because of limited space and the lack of flush-joint tubing. Therefore, an air-lift system was designed to blow out water by compressed air.

A swabbing reel with 100 m of flexible polyethylene tubing and a lubricator-type adapter sub were manufactured by BPT/Lynes. This configuration was used effectively and frequently to blow down the fluid level in, and remove water from, the tubing. Compressed air entered the tubing string and flowed down the annulus between the tubing interior wall and the swab tubing exterior wall. The compressed air forced the water down in the annular space in the tubing string and it returned to the surface through the swab tubing and into a collection/ measurement device.

3.1.1.4 Surface pressure measurement system

NAGRA specified that packer inflation pressure be monitored not just during inflation as it had been done previously, but continuously throughout testing. These data provide documentation of the packer response related to any changes in borehole diameter due to instability or clay swelling, and the interval, annulus or bottomhole pressures during individual events.

Tool modifications made to allow packer inflation from the surface enabled the in-line packer pressure to be monitored solely by adding an additional pressure sensor and making valving changes at the surface. Changes were also made to the data acquisition software so that multiple sensors could be monitored in real time, including the packer pressure gauge.

Pressure in the packer inflation line was monitored at the surface using a BPT/Lynes Single Pressure Probe (SPP). This equipment was used, in part because of its similarity to the TCWL sensor. Specifications for the SPP are similar to those for the TCWL and are given in Table 3.1. The SPP was also used to monitor the injection pressure of the gas during the HGB/55.5D gas testing activities. Packer pressure was monitored only at the beginning and end in this instance.

Temperature measurements coincident with the surface pressure readings reflect the environmental conditions in the drilling gallery and are not important to the testing program or the results.

3.1.1.5 Flow measurement and control system

Originally, NAGRA anticipated that some of the intervals might flow water above the level of the drilling gallery floor or that injection tests might be done as part of the hydraulic testing program. An effective system of flow measurement and control was needed to be able to accurately monitor the volumes and rates of fluid flow under these testing conditions.

The system developed to conduct and monitor events with flow is shown schematically in Figures 3.6(a) and 3.6(b). It consisted of:

- Flow manifold board and accessories
- Flow meters
- Injection pumps
- High volume tank

Flow manifold board and accessories

The operational limitations of the site as well as the explosion-proof requirements for the borehole area necessitated that certain electronic equipment be used in the Seelisburg tunnel control room. The flow manifold board was used to monitor and control pressure and flow between the wellhead and the control room. Stainless steel tubing of 12.5 mm ID was mounted on the tunnel wall between the wellhead and board.

The pressure gauge and control valving on the board allowed flow or pressure routing prior to or during events to be prepared and monitored.

Flow meters

Flow through the system was monitored using high-precision mass monitoring digital recording flow meters. Specifications for the equipment are in Table 3.2. Both water and gas flow were measured during testing. Rates and cumulative volumes during flow were automatically displayed and recorded as part of the data acquisition system.

The meters successfully monitored flows over the range of specifications. An important feature in the meters is their versatility. One was able to be converted from water to gas flow monitoring in the field for the injection testing done in the HGB/55.5D gas test. The ability to plot rate versus pressure during the testing was useful and justified the use of the digital rate accumulator connected to the system.

Meter calibration was originally done at the suppliers' factory. On-site measurements verified the approximate volumes and flow rates. A supplier representative in Switzerland performed the gas calibration on-site.

Injection pumps

Two sets of injection pumps were used during the project. They were able to be used over most of the range specified. During constant rate injection, low volume rates on the order of 0.1 to 0.5 ml/min were more difficult to maintain with frequent adjustment against continuing pressure increases necessary to keep the rate constant. Otherwise, the low flow rates required were successfully achieved. Specifications are in Table 3.3.

High volume tank

NAGRA had a high volume tank constructed to provide a large shut-in volume compared to that available form the downhole FAV. Use of this tank enlarged the effective radius for pulse tests. The tank volume was commonly connected in-line with the flow manifold board.

The concept and hydraulics of a higher shut-in volume system are ideal for conditions where the interval's hydraulic head is above the fluid level of the shut-in volume. However, at Oberbauenstock, hydraulic heads in the borehole were below the tunnel floor and therefore, below the tank. In some tests, the interval accepted fluid faster than it could be delivered through the lines to the wellhead from the tank. In this situation, there was suction in the system. Similarly, when the pressure under shut-in conditions decreased below the suction level of the tank, then the dynamic response of the interval being tested was influenced by the suction inside the enclosed tank system.

The results of using the tank as a larger shut-in volume for pulse injection tests were generally consistent with the results of the pulse tests conducted with the downhole FAV shut-in volume. However, many of the events that included the tank system were not able to be quantitatively compared to other event responses because of the uncertainty in the suction effect on the dynamic response of that particular event.

3.1.2 Water sampling equipment

GLL contracted with WNRE/AECL for the use of both downhole pumps and pressurized sampling vessels for collecting water samples. The swabbing line described in Section 3.1.1.3 was used to clean up the interval prior to sampling and to a lesser extent to remove fluid for samples.

3.1.2.1 Sampling pump

Sampling fluids from depth in small diameter tubing is difficult due to size restrictions for the equipment and the requirement of maintaining the sample free of air. The WNRE/AECL pump shown schematically in Figure 3.7 was used to remove samples of fluid from the HGB/83.3D and SA/100.2S intervals.

The pump operates using an air compressor. The pump is lowered into the tubing string on a 500 m umbilical line containing one hydraulic line for the sample, one hydraulic line for the compressed air and a wireline strength member. Water enters the pump's rubber bladder when the internal bladder pressure is lower than the pressure of the fluid outside the pump. By cyclically pressurizing the bladder from the outside, volumes of fluid move up through a small diameter delivery line to the surface. The rig hydraulic system was connected to the reel to move the pump in and out of the tubing string.

The pump was not able to be operated efficiently due to the low hydraulic head conditions, and the friction loss in the 500 m length of cable connected to the pump. Yield was not continuous. Site experience indicated the pump required at least 1 m of water head to operate effectively. In both sampling exercises, once the production had lasted for a while, interval yield was slow and the subsequent hydraulic head conditions were just about at the minimum operational requirement.

The pump had not previously been used with lengths of 500 m of supply line. During operations, the pressure cycling of the bladder had a delay in delivery. It is likely that the compression of the fluid within the supply line wrapped around the reel at the surface may have also reduced its efficiency. Difficulties experienced in obtaining samples may also have arisen because suspended sediment in the fluid plugged the check valves.

The pump was able to remove fluid from the tubing string in both interval tests, and this fluid was retrieved from the pump when it was pulled to the surface.

NAGRA's Bennett Pump was used to lower the fluid level in the SA/160.6S interval. This pump operates using compressed air to drive pistons. It has a more intricate internal valving arrangement that is susceptible to clogging when there are fine amounts of sediment in the water. Samples were not taken using this pump at Oberbauenstock, but it represents an alternative for future programs.

3.1.2.2 Pressure sampling vessels

Sampling formation fluid under the same pressure conditions as occur in the interval is a requirement for good chemical characterization of the ground water. Pressurized sampling vessels were lowered into the tubing string on the same wireline used for the squeeze pump. They can be used in-line with the pump or used independently. Vessels can be stacked in series to obtain a larger volume .

Pressurized samples were taken at the end of the SA/100.2S interval testing. Only in this interval was there an adequate volume for sampling. A schematic diagram of the vessel is in Figure 3.8.

3.1.3 Data processing equipment

The core and a major facilitating component of the testing and analysis procedures was the updated computer hardware and software developed by GLAG specifically for NAGRA's Oberbauenstock project. The data processing system consisted of Hewlett Packard hardware and customized Unix-based software. The central processing unit (CPU) was an HP320 computer to both data acquisition and data display and storage peripherals. A schematic of the system is shown in Figure 3.9. Components are listed in Table 3.4.

3.1.3.1 Data acquisition

The system was operated with multiple sensors sending data to the CPU. The acquisition setup allowed all three sets of data from the downhole sensors, surface sensor, and digital flow meter to be monitored within individual acquisition times of 6, 30 and 1 seconds, respectively. Typical cycle time for data acquisition when all three components were on line was about 40 seconds.

3.1.3.2 Data display and manipulation

The data acquisition system allowed graphical display, printout and storage of the data essentially concurrent with acquisition. Operating in the Unix environment, obtaining the data was given priority, but a variety of other tasks could be performed without loss of signal input.

Printing and plotting was done in real time on peripherals dedicated solely to the data being acquired. At the same time, any real time data could be plotted on the HP320 screen. Previous data or all the data from a given test interval could also be plotted first on the screen, and then, if desired, a hardcopy plot and printout could be made for a permanent record on the background printer and plotter.

Real time plots were typically linear representations of specific events during the part of the testing in an interval. Semi-log or log-log plots for analysis could also be made in real time or later. The dual printing and plotting capability enabled virtually simultaneous analysis as the data were being acquired.

An additional part of the simultaneous acquisition/analysis function was that model simulation could also be done and compared to the data being acquired. Typically, multiple runs of the GLIMPSE wellbore model, described in Section 4.1.2.2, were made and their results plotted on the screen. The test data were plotted as the event was ongoing and data were continuously updated on the screen.

Data were stored as they were acquired both on 3 1/2-inch, 720KB diskettes and on the 40MB hard disk. Data from each interval test were subsequently transferred to 5 1/4-inch diskettes in ASCII format for in-house use at NAGRA.

3.2 Testing Methods

Pressure transient methods were used to test the intervals in the three boreholes. The methods used are similar to those that have been used previously for reconnaissance-type investigations by NAGRA and by others at existing and potential waste disposal sites. NTB 87-3 summarizes considerations that NAGRA followed when designing the testing methods for the low permeability rock environment.

Borehole testing was separated into both 'screening' and 'detailed' interval categories. Screening tests were done in the HVB and HGB boreholes after drilling and geophysics were completed. Only detailed tests were done in the SA borehole. The purpose of the screening tests was to test larger sections of the borehole looking for the potentially more permeable discontinuity zones. The purpose of the detailed tests was to identify the characteristics of permeable features within the screening test zones deemed of interest to the project.

Screening tests generally lasted from 24 to 36 hours and generally consisted of a single pulse and withdrawal event after the initial compliance and static pressure monitoring events.

Detailed tests generally lasted longer and consisted of more and different types of events, depending primarily on the relative permeability of the zone.

A consistent method of approach for the format and schedule for testing was followed in most instances. This allowed a relatively rapid on-site qualitative comparison of different interval responses early in the testing of each interval and established the framework for further quantitative analyses.

Testing that was done between the inflation and deflation activities in each interval consisted of one or more of the following types of events:

- Compliance period
- Pressure recovery
- Pulse injection
- Slug injection or withdrawal
- Injection with constant rate or pressure
- Sampling

Table 3.5 lists the occurrence of events conducted in each of the intervals tested at Oberbauenstock. Figure 3.10 illustrates these types of events based on an example from the SA/298.0D interval.

3.2.1 Compliance period

The purpose of the compliance period, labelled COM on the pressure-time plots, was to allow the packers to fully expand under the downhole conditions. The beginning of the compliance period was commonly defined as the time at which the constant pressure source was attached to the inflation line at the surface. Compliance generally lasted about an hour during which time the downhole shut-in valve was open and the interval was exposed to the pressure of the fluid level in the tubing string. Compliance ended with the closing of the downhole shut-in valve, commonly beginning the start of the static pressure recovery monitoring period.

There was no compliance period in three tests when testing of SA borehole. The test objectives required the tubing string fluid level to be below the expected hydraulic head of the interval at the beginning of testing. Therefore, the shut-in valve was opened soon after inflation.

3.2.2 Pressure recovery events

Pressure recovery events refer to when the interval response is recovering towards the interval static pressure under shut-in conditions following another event.

"Psr" event

The recovery after the standard compliance period was referred to as the 'Psr' event since this event represented the first opportunity to monitor the shut-in response back towards static pressure after inflation on the interval (Figure 3.10). Psr events were conducted in 29 of the 30 intervals tested.

"Pr" event

Pressure recovery events were other shut-in responses generally following slug or injection tests. In some instances, these events referred to events with downhole shut-in conditions following a pulse event that used the surface tank system. Pr events were identified sequentially with numbers during testing in each interval. A total of 38 Pr events were carried out.

3.2.3 Pulse events

A pulse event involves inducing an 'instantaneous' pressure change opposite the interval and monitoring its response towards the previous condition, generally static, under shut-in conditions. As such, there is only a small volume of fluid flow in a rigid system during the event. The pulse test is, therefore, a Pr-type event but with an induced initial pressure at the beginning. No measurement of the volume change or flow rate could be made during OBS-1 testing due to the equipment used.

A total of 37 pulse injection events were conducted during testing, 29 using the downhole FAV and 8 using the surface tank. No pulse withdrawal events were done. The pulse was generated by pressuring the line at the flow manifold board and subsequently opening the downhole FAV. Once the initial pressure was observed, the FAV was closed, unless the tank was being used as the shut-in volume. If the tank was being used, the valve was left open.

The amount of pulse event overpressure was initially established as a factor of between 20 and 50 times the pressure change that had occurred in the interval in the preceeding hour. In this manner, even if the preceeding response had not stabilized prior to the pulse event, the overpressure response would be distinguished and therefore analyzed for hydraulic conductivity. Experience in the first interval tests indicated that the 50-times factor did not always allow adequate resolution for the response. Subsequent testing relied on overpressures of up to 5 bars, regardless of the interval pressure value.

The rate of response of a pulse event is dependent upon the shut-in volume of the system in addition to the hydraulic parameters of the interval.

Downhole volumes below the FAV were nominally on the order of 50 to 150 litres, compared to nominal tank and surface system shut-in volumes of about 850 to 1000 litres.

3.2.4 Slug events

Slug events involve the flow of water either, from the interval into the tubing string (withdrawal), or from the tubing string into the interval (injection). In either instance, the flow involves a change in the liquid level in the tubing string. The downhole interval pressure sensor monitors the pressure which depends on the liquid level above the transducer. Flow rates are calculated from the fluid density and the pressure change data. In all cases, the specific gravity of the fluid in the tubing string was assumed to be 10 kN/m^3.

A total of 10 slug injection and 13 slug withdrawal events were conducted. The slug injection tests were initiated by opening the downhole FAV after the tubing string had been filled, generally to the top. The slug withdrawal tests were initiated by opening the downhole FAV after the swab tubing had been used to lower the fluid level below the expected pressure of the interval.

The magnitude of slug event initial conditions was limited to the length of the tubing string for injections and the depth of the FAV for withdrawals. Typical injection pressures were three to four times greater than the interval pressure whereas withdrawal conditions represented levels 50 to 80 percent lower than that of static conditions. Withdrawal conditions were not as easy to implement since the fluid level in the borehole was so low.

Slug withdrawal conditions where the tubing string was virtually empty down to the FAV were used to test the SA/137.0D, SA/157.0D and SA/196.5D2 intervals. This condition for testing was attained but the open-tubing compliance period was dropped in these instances. Instead, the packers were inflated with the FAV closed and it remained closed throughout the Psr until it was opened at the beginning of the withdrawal event.

The rate of response of a slug event is dependent upon the radius of the tubing string which determines the volume per unit change in head. The same tubing string with a radius of 41 mm was used for all slug events.

3.2.5 Injection testing

Injection tests were done in a total of six intervals. A constant rate approach was attempted with water in three intervals and in one interval with gas. Constant pressure tests were done in three different intervals with water.

Constant rate tests are favoured by some scientists because they are apparently easier to analyze compared to constant pressure tests (NTB 87-03). Pressure changes are able to be more precisely documented and indicate changing boundary conditions compared to the ability to measure changing rates while maintaining constant pressure conditions.

Constant rate attempts with water required continual adjusting of both the pump settings and the flow manifold board valving to maintain the rate. Even with these adjustments, rates fluctuated by as much as 20 percent, particularly in the intervals with transmissivities lower than 1e-8 m2/s. Better average results were obtained when the totalized volume divided by the elapsed pumping time was used to determine the rate rather than individual spot readings of the rate on the flow meter.

Constant rate tests with water and gas in the HGB/62.5D and HGB/55.5D intervals, respectively, were more successful (Figures 3.11 and 3.12). In these instances, the transmissivities were on the order of 1e-7 to 1e-6 m2/s. This higher permeability allowed pump and board valve changes to be made more gradually and rate changes were generally able to be maintained within one to two percent of the target value.

Constant pressure tests were logistically easier to run since a constant pressure source could be readily maintained from bottled nitrogen or a nearby high-capacity water line. Rate measurements were made using the high precision flow meter in most instances. The long-term injection testing in SA (open hole) and at the end of testing in the SA/157.0D interval (Figure 3.13) was done using the drilling rig pump. Flow volumes and rates were determined based on changes in the liquid level in the mud tanks.

Pressure recovery events generally followed the two type of injection tests.

4. INTERPRETATION METHODS AND REPORTING

The purpose of this section is to describe first, the techniques used for interpretation both in the field and subsequently after the completion of testing, and second, how the results from these analyses were designed to fit within the project reporting scheme.

4.1 Interpretation Methods

Efficient on-site data analysis during testing was a primary project requirement. Interpretation methods were, for the most part, restricted to the standard approaches associated with homogeneous, porous medium conditions.

4.1.1 Field analysis

The first step associated with the assessment of the field data was compiling and reviewing the drilling, core recovery, geologic and geophysical data for the interval. In this manner, the interval's general hydrogeologic setting was understood prior to and during the testing and readily available as background to assist with the field analysis. Analyses for each interval response were done first in the field during or shortly after the end of testing. Field interpretations used the standard type-curve matching and straight-line approximation techniques given in Table 4.1. In some situations, diagnostic early time log-log plots were used and on occasion, simulations were run and compared to the data. Figure 4.1 illustrates typical field interpretation methods done at the time of testing. These analyses did not include the effects of borehole history, non-ideal initial conditions, gas effects, shut-in period temperature changes, non-equilibrium conditions prior to testing or skin effect. Homogeneous isotropic porous medium conditions were assumed for all field analyses.

4.1.2 Interval analysis

This second level of interval response interpretation was done after the testing in an interval was completed. It included, where necessary, the above-mentioned factors except skin effect. Including skin effect in the interval analysis was not considered cost effective at this stage and was left for the zones of more interest to NAGRA that will have additional detailed analyses conducted in future.

The second level of interpretation involved first, compiling the borehole history estimate pressures, and second, attempts at bounding the test data to further quantify the ranges associated with the interval hydraulic parameters.

4.1.2.1 Borehole history

The first part of the bounding approach was to estimate the pressure the interval had been exposed to prior to testing, otherwise referred to as the interval's borehole history. Figure 4.2 and Table 4.2 illustrate both how simple and how complicated borehole history pressure can be for an interval.

An interval's pre-testing pressure history is estimated from the drilling data and other borehole activities such as geophysics and testing. Drilling through the interval is the start of the pressure history. Continued drilling below the bottom of the interval exerts pressures which are a function of the fluid level and specific gravity of the mud. Subsequent geophysics and running the testing equipment in to the first depth is the next activity. During this time, the fluid level can very considerably as it did in both the HGB and SA boreholes, or it can be near the surface most of the time as was the case for the HVB borehole. Figure 4.2(a) and Table 4.2(a) illustrate an example of an estimated history that begins after about 16 hours of three periods of relatively consistent pressure that occurred during 3 different pre-testing activities.

A more complicated example is illustrated in Figure 4.2(b) and Table 4.2(b). In this instance, the HVB/52.7D interval was exposed to:

- standard drilling and logging activity full annulus fluid level pressures,
- bottomhole pressure falloff response during the screening test in the overlying interval,
- interval pressure for the screening test that included the interval,
- annulus pressure during the next two screening tests, removal and run-in of the tool, and,
- bottomhole pressure falloff responses during the casing test and the next two detailed tests.

Compilation of borehole history pressure estimates is a prerequisite to understanding and conducting a detailed interpretation of the interval response during testing. The pressure history of the pre-testing events can then be input into the simulation model and analyses done that include the effect of these pressures on the response of the interval.

4.1.2.2 Simulation modelling

The wellbore response model, GLIMPSE, was used in the attempts at bounding the test data. GLIMPSE is a one-dimensional finite difference model that calculates the pressure distribution around a borehole in a confined, homogeneous, isotropic porous medium with a transient, laminar, radial flow field. The model incorporates the wellbore storage effect based on the interval volume and fluid properties. Event conditions can be:

- constant or linearly decreasing pressures,
- slug test, with or without a pressure change at the start of the test,
- pulse test, with or without a pressure change at the start of the test, well temperature constant or variable,
- constant rate or pressure pumping in the well, or,
- shut-in pressure recovery, well temperature constant or variable.

The model can also simulate a finite thickness skin with specified skin zone hydraulic conductivity. However, including this additional variable considerably lengthens the time required for analysis. Therefore, this option was not used in the Oberbauenstock bounding analyses.

The first step in the simulation modelling was to set up the borehole history events as either constant pressure or linearly changing pressures resembling the estimated pressure for all the pre-test events. This commonly involved at least three and in the most complicated history, HVB/74.5D, there were 18 distinguishable history events, some of which had widely varying pressures.

The next step was to accurately determine the initial conditions and duration of each of the interval events. All event conditions from the start of compliance until the end of testing were assigned appropriate model conditions.

Pulse events, for example, rarely have instantaneous conditions at the beginning. Instead, the downhole valve is commonly open for up to 30 seconds during which time the pressure is relatively constant at a value similar to the pulse event start pressure. Including this short time period as a separate event in the interval simulation becomes important as the permeability of the interval decreases.

Attempts at bounding the test data began once the borehole history and interval events were defined. Initial simulations were run using the field analysis results. When these results were not similar to the data, it was likely because of the effect of borehole history. Thereafter, static pressure, hydraulic conductivity and storativity parameter values were varied over reasonable ranges for the interval to attempt to bound the data for all tests. The results of the runs were plotted and visually compared to the data until it was bounded or, in some instances, until most possible conditions had been evaluated, even though bounding had not been successful.

In some instances, the Psr event had to be simulated as a series of constant pressure or linearly changing events due to suspected packer squeeze. Similarly, most of the pulse events done using the surface tank were considered as specified constant or linearly varying pressure events rather than as pulse tests.

Bounding was not always successful. In some instances, the porous medium model conditions likely did not reflect the in-situ environment which was one or more interconnected fractures. In other cases, skin effect was likely present. In three tests of the essentially the same interval (HGB/55.5D), skin effect changed during testing due to breakthrough or clean-up of the interval.

Attempts to bound the data were made in all instances for the 30 interval tests. Many were regarded as successful. Those that were not successful had a response that suggested skin effect, limited reservoir or inappropriate model conditions. Further more detailed analysis is needed to clarify the interval hydraulic parameters for those specific instances that are of interest to NAGRA.

4.2 Reporting

Four types of reports were issued for this project. The short duration of 98 days required continued communication and feedback between the various contractors and NAGRA to maintain information flow and provide the basis for daily activity planning.

The three types of reports submitted during the testing program were:

- Daily Operations Report
- Quick Look Report
- Interval Report

This report, the Final Field Report, contains the compilation of the work done, the data acquired and the interpretation results.

4.2.1 Daily operations report

The daily operations report (DOR) served as a means of identifying the testing work done each day and the amount of resources required to do that work. Action items requiring quick resolution were highlighted. DOR's were submitted daily and signed by both the GLL and NAGRA project managers.

4.2.2 Quick look report

The quick look report (QLR) provided the opportunity to summarize each interval's testing activity. QLR's were submitted for all intervals tested shortly after the end of testing in the interval. The pertinent drilling, geology, geophysics, borehole history and interval testing facts were presented along with tables of the pressure changes in the intervals above, below and in the interval. Analyses results from the field were compiled so that event hydraulic characteristics could be compared. Five linear plots illustrated the downhole and surface (packer) sensor pressure and temperature over the duration of testing. Remaining plots documented the field analysis results.

Appendix C6, SA/196.5D2 contains an example of the QLR submitted for that interval.

4.2.3 Interval Report

The purpose of the interval reports (IR) was to prepare a stand-alone document for each interval tested. All pertinent background borehole and interval information as well as all data and field and bounding approach analyses was contained in it. The program was originally scheduled so that the IRs would be completed within 10 days of finishing testing in the interval. However, since testing of HVB and HGB was done in continuous blocks of time, a backlog developed and submission of the reports had to be delayed, for the most part, until after the end of testing.

The IR's serve as the reference for any future analysis that may be done for the interval. NAGRA maintains these IRs as in-house technical documents (NIB 88-02, A-J for HVB tests; NIB 88-03, A-L for HGB; NIB 88-04, A-H for SA). Summaries of them are included in appendices to this document.

4.2.4 Final field report

This report is the final field report. It compiles and presents the approach, rationale and results of the testing done during the Oberbauenstock program. In particular, this report is designed to document the work done at the site. As such, it illustrates the types of testing and analysis methods used and the trends and uncertainties in the borehole hydraulic parameter results obtained using the analysis approach used to date.

5. CASING TESTS

The purpose of this section is to describe the work completed to evaluate the compliance of the packer system.

Two tests in casing were performed. Test 1 was done in the HVB casing after completion of the HVB screening tests. Test 2 was done on the surface in subhorizontal casing near the entrance to the tunnel.

5.1 Casing Test 1

The purpose of the first casing test was to determine if packer pressure changes after inflation caused pressure decreases in the interval or below the bottom packer. No quantitative volume-related measurements were made during this test to attempt to quantify system compliance or evaluate the effective radius value. Quite simply, concern that packer pressure falloff during the screening tests may have influenced the interval pressure response was being investigated.

The downhole equipment was set in the casing on June 2, 1986 prior to proceeding with the HVB detailed tests. The top of the lower packer was at 18.4 m and the bottom of the upper packer was at about 13.2 m BRP (Figure 5.1). The packer straddle length was about 5 m.

The six activities associated with casing test 1 as shown on Figures 5.2 through 5.4 included:

1) Inflation sequence with an initial inflation line shut-in pressure of about 6650 kPa, (INF1).

2) Monitoring pressures with the downhole shut-in valve open (COM).

3) Monitoring pressures with the downhole shut-in valve closed (Psr).

4) Increasing the inflation line pressure to an initial shut-in pressure of about 5500 kPa and monitoring other pressures with the downhole shut-in valve closed (INF2).

5) Increasing the interval pressure and monitoring the packer and other pressures responding to the increase with the downhole shut-in valve closed.

6) Deflation.

5.1.1 Packer inflation pressure response

The equipment was lowered in the casing and the packers were inflated with the shut-in valve open. Inflation pressures were increased to about 6400 kPa, allowed to falloff for about 20 minutes and then increased again to about 6650 kPa (Figure 5.2, (A)).

This method of packer inflation was similar to that used to conduct the HVB screening tests. Point A represents the final packer inflation pressure prior to the line being shut-in at surface. Thereafter, the packer pressure decreased as the packers continued to expand and seal against the casing.

The packer pressure had decreased by about 2400 kPa four hours later (Figure 5.2, (A to B)). The inflation pressure was increased to about 5800 kPa to observe the effect on the interval pressure. The pressure falloff was monitored for an additional 90 minutes at which time the interval pressure was increased. This increase was done to observe if the packer pressure would change.

The packer pressure increased by about 100 kPa with an interval pressure increase of about 750 kPa (Figure 5.2, (C)). After the increase, the rate of packer pressure decline was similar to prior to the interval being overpressured.

The rate of pressure falloff in the packers at the end of the Psr event was lower than immediately following inflation. After the second inflation pressure increase, the rate of pressure decrease was similar to at the end of the Psr event. The decreasing rate of change illustrates the reduced movement of the packers with time, even at increased pressures.

5.1.2 Interval pressure response

Figure 5.3 illustrates the interval pressure response during testing.

The pressure decreased in the interval until the packers sealed. It was stable as the fluid level in the tubing remained constant with the shut-in valve open (Figure 5.3 (COM)). There was no pressure change evident in the interval even with the two increases in packer pressure to 6400 to 6650 kPa.

The downhole shut-in valve was closed about 1 hour after the packer pressure line pressure had been shut-in at 6650 kPa (Figure 5.2 (A)). The interval pressure decreased by 30 kPa during the following four hours (Figure 5.3 (Psr)). This decrease was attributed to increasing internal volume between the packers as they continued to expand.

Interval pressure increased from 200 kPa to 235 kPa when the packer inflation pressure was adjusted the second time (Figure 5.3 (INF2)). It decreased about 5 kPa in the following 90 minutes.

Interval pressure was increased from 230 to about 975 kPa to observe first, if the other pressures responded and, second, if the interval pressure held constant in the casing.

Increasing the interval pressure did not show any long-term effect on the bottomhole or annulus pressures (Figure 5.4). Packer inflation pressure did increase as discussed above. Surprisingly, the interval pressure decreased by about 250 kPa at a relatively constant rate during the following 6 hours (Figure 5.3 (Pr1)).

5.1.3 Bottomhole pressure response

The bottomhole pressure below the lower packer increased from 260 kPa to 280 kPa during inflation as packers sealed against the casing.

Once the packers sealed, the pressure began decreasing and continued to decrease over the entire duration of testing (Figure 5.4). The final pressure was 130 kPa.

Packer and interval pressure changes had no effect on the bottomhole pressures. The small fluctuations shown in the P1 readings at the onset of several events were caused by adjusting "gain" levels on the frequency counters.

5.1.4 Annulus pressure response

The annulus pressure remained stable between 215 kPa and 216 kPa during testing (Figure 5.4). Small fluctuations in P3 readings occurring at the same time as those in P1 were caused by changes in the frequency counter "gain" settings.

5.1.5 Results and conclusions

Results from the testing indicated:

1) Relatively large packer pressure changes in the order of thousand of kPa could cause interval pressure changes in the order of tens of kPa.

2) Decreasing packer pressures occurred simultaneously with decreasing interval pressures.

3) Bottomhole and annulus responses were not noticeably affected by interval or packer pressure changes.

The reason the interval pressure dropped during the Pr1 event is not known with certainty. Similar testing conducted in casing at the surface later in the testing program showed virtually no pressure drop when packer inflation remained constant. BPT/Lynes procedures at their warehouse showed much smaller interval pressure changes using the same packers inflated with a shut-in gas pressure. All the other tests in casing were done using a single piece of steel. Downhole, there were two welds in the casing opposite the zone tested. These welds may have been the pathway for pressure relief. Alternately, the pressure falloff could have resulted from continued packer deformation which resulted in a changing volume between the two packers.

The uncertainty in the system response led to an immediate change in the procedure for maintaining packer inflation pressure. A constant pressure nitrogen source was connected to the inflation line. Thereafter, packer pressure changes were generally limited to about a 100 kPa gradual decrease over 20 to 40 hours of testing. In this manner, the constant packer inflation line pressure was expected to reduce compliance effects.

5.2 Casing Test 2

The purpose of the second casing test was to measure the wellbore storage and evaluate the effective radius value of a rigid system and to compare these values with the theoretical results used in the analysis of the interval tests. The variability in such a test is derived from the packer compliance that occurs following inflation and the packer displacement resulting from a changing pressure differential across a given packer element.

This test was performed on the 16 and 17 of June, 1987, after the HVB borehole testing was completed. The testing set-up (Figure 5.5) was prepared at the entrance to the Bauen access tunnel of the Seelisburg road tunnel. Activities were performed under NAGRA's supervision through their subcontractor Solexperts.

The test was done by inflating the packers in a steel casing and injecting or removing measured volumes of water into both the packer interval and below the lower packer. Volumes of water were measured using a high pressure site-glass panel. Pressures were recorded above, between and below the packer elements using the BPT/Lynes TWCL. The pressure between the two packers was monitored by the P2 transducer and is hereafter referred to as the P2 pressure. The P1 transducer monitored the pressure below the lower packer and P3 above the upper packer (atmospheric pressure). The WNRE/AECL FAV was installed above the Lynes TWCL to isolate the P2 interval from the atmosphere.

Figure 5.5 shows the testing equipment configuration. Two valves were fitted to the casing to allow injection and withdrawal of water into both the P1 and P2 intervals. The BPT/Lynes tool configuration remained unchanged from the normal testing set-up. The straddle length was reported to be 3.1 m with an associated 'shut-in' volume of about 21.5 litres. The P1 volume has been calculated to be about 8 liters.

The steel pipe was raised at one end and filled with water to minimize the air entrapped within the interval.

The testing was done in two parts in an attempt to approximate the two different methods of packer inflation used during the HVB testing. Part 1 was conducted with the packer inflation line closed to replicate the approach used for the HVB screening tests and casing test #1 described above. Part 2 was conducted with the constant pressure source connected in-line to maintain a constant packer pressure. This was the technique used in the balance of the HVB testing and all of the HGB and SA intervals. The packer pressure response for the two parts is shown in Figures 5.6 and 5.7.

Temperature during the testing period changed by about 2°C. As shown in Figures 5.8 and 5.9, these changes occurred in the early stages of Part 1 and may have affected the responses.

In NTB 87-03, a theoretical value of the effective radius with the following equation is presented:

$$r_e^2 = (V_w C_w P_w g + Sc) / \pi$$

where

r_e is the effective radius
V_w is the enclosed volume of water (eg. m^3)
C_w is the compressibility of water (eg. $Pascals^{-1}$)
P_w is the density of water (e.g. kg m^{-3})
g is the acceleration due to gravity (eg. m sec^{-2})
sc is the system volume compliance per unit head change

The effective radius can be imagined as the radius of a tubing, 1 meter long, from which an enclosed volume of water, when injected into the packed-off interval, causes a unit increase in pressure head, all values in consistent units.

The casing test had an interval volume of about 21.5 litres or 0.0215 m^3. This translates into a 'rigid system' with an effective radius of 0.17 mm. The interval below the bottom packer had a shut-in volume of about 8 liters. Using the above equation, this yields a theoretical 'rigid system' effective radius of 0.10 mm.

However, no system is perfectly rigid. The Oberbauenstock testing system was composed of two rubber packers and several meters of stainless steel tubing. The packers in particular have some compliance which would mean that there was an increased field effective radius. The casing test was designed to measure this compliance in an otherwise rigid system.

The experimental values of the effective radius were calculated from the injection (or withdrawal) of a fixed volume of water into the packed-off interval and measuring the increase (or decrease) in pressure. This provides a dV/dP (or dV/dh) term which is equivalent to the cross-sectional area of the tubing of which 'r_e' is the radius.

The field value of the effective radius is therefore: $r_e^2 = \frac{dV/dh}{\pi}$

The system compliance is the difference between this and the theoretical value presented earlier.

Table 5.1 provides a summary of the start and end conditions of the activities conducted, and the pressure responses for these events are shown in Figures 5.10 through 5.14.

5.2.1 Casing test 2 - part 1

Part 1 lasted about 17 hours. The P1 pressures increased rapidly in response to the start of packer inflation (Figure 5.10, A to B), continued to increase to Point D and decayed over the remaining shut-in recovery activity (Figure 5.10, D to E). The increase from Points C to D coincides with the temperature increase shown for the same period in Figure 5.8.

The FAV was open during inflation such that the P2 interval was exposed to atmospheric conditions. No packer inflation squeeze was seen in the interval. The FAV was closed about one hour after inflation (Figure 5.10, C) with no apparent P2 response.

Two pulse injections were performed at the end of part 1 to determine the effective radius. These are shown in Figure 5.10 between Points G and H and in detail in Figure 5.11. The first pulse injection is defined by Points A to D in Figure 5.11. This event was terminated at Point E because of an inadequate pressure increase. A second pulse was applied to the P2 interval which generated about a 450 kPa pressure increase. This is shown as the response between Points E and F in Figure 5.11 and is referred to as Test 1, Event 1. This pressure was subsequently released between Points G and H by opening the P2 valve. About 56 ml of water were recovered.

The P1 response to this activity is shown in Figure 5.10 between Points E and F.

5.2.2 Casing test 2 - part 2

Part 2 was conducted with the constant pressure source connected such that the packer pressure remained essentially constant over the testing period (Figure 5.7). The interval response during Part 2 is shown in Figures 5.12 through 5.14.

Casing test 2 - part 2 had three events (2 through 4) that yielded data for effective radius calculations.

Event 2) This event was the opening of the P1 valve as defined by Points B and C in Figure 5.12. About 54 ml of water were recovered. The increase in the P1 pressure preceeding this event was the result of an increase in the packer pressure (Table 5.1).

Event 3) This event was a series of injections of known quantities of water into theP2 interval. These are shown between Points H and I in Figure 5.12 and in more detail in Figure 5.13. Figure 5.14 shows the corresponding P1 increases.

Event 4) The final event was the opening of the P2 valve (Figure 5.12, J to K). About 66 ml of water were recovered.

The P1 valve was opened at Point E-F (Figure 5.12) exposing the P1 interval to atmospheric pressure. The water released at this time was not measured.

5.2.3 Results

The effective radius (r_e) is calculated from the following equation (NTB 87-03):

$$r_e^2 = (V_w S_{sw} + sc)/\pi$$

The following are the r_e calculations from the events described above:

Event 1)
dP = 520 kPa = 53 m = dh
(P2) dV = 56 ml = 0.000056 m^3

r_e = 0.58 mm

Event 2)
dP = 3421 kPa = 348.7 m = dh
(P1) dV = 54 ml = 0.000054 m^3

r_e = 0.22 mm

Event 3)
dP = 1310 kPa = 133.5 m = dh
(P2) dV = 88.2 ml = 0.000088 m^3

r_e = 0.46 mm = dh

Event 4)
P = 1216.3 kPa = 124 m = dh
(P2) V = 66 ml = 0.000066 m^3

r_e = 0.41 mm

The 66 ml of water recovered in event 4 is less than the 88 ml injected. This is thought to be a result of the release of the P1 pressure and the associated packer displacement. The effective radius value is therefore unrealistic.

Table 5.2 summarizes these results. The system compliance resulting from packer movement has also been calculated using the above equation. From this, an 'effective volume' has been back-calculated and shown in the last column. The effective volume is the volume of a rigid system that would generate the same response as recorded in the field. For the purpose of simulations, the effective volume would be more appropriate. To date, however, the sensitivity of changing the simulations to the effective volumes has not been done.

Figures 5.13 and 5.14 display, respectively, the P2 and P1 responses to the injections. In an effort to correlate these two responses, a comparison has been done between the magnitude of the respective pressure increases and the volume of water injected. The data are presented in Table 5.3.

5.2.4 Conclusions

The purpose of the second casing test was to attempt to measure the compliance of the packer system. The value for compliance has been reported in Table 5.2 in the form of both an area, and a volume that represents the additional volume of water required to compensate for the 'movement' of the packers. The effective volumes calculated for the testing events are from about four to thirteen times larger than the estimated volumes. Investigations on other projects indicate that underestimating the shut-in volume by an order of magnitude results in underestimating the transmissivity by a similar factor. Therefore, if the actual effective shut-in volumes were higher, the transmissivities would be higher by a similar factor. This means that pulse test events could have higher transmissivities than reported if there was packer compliance or air associated with the downhole system.

In all events, packer inflation pressure is higher than the adjacent interval pressure. Therefore, the packers should not be moving. However, small changes in shape may occur in the upper and lower ends of the packer depending on the pressure differential across the packer element. The compliance measured may reflect this change in shape.

Comparison of the compliance values in Table 5.2 supports this approach. The compliance reported for event 2, a P1 response, is about one third of the P2 compliance. The P1 volume is bounded by a single packer, the P2 volume by two packers, one of which is exposed to atmosphere. The P2 compliance would therefore be expected to be at least twice as large. In addition, the values resulting from event 1 may not be representative given the decreasing packer pressure.

There is an additional factor that needs to be considered in the casing test results. This is the potential presence of air in the system during testing. Throughout the testing, air bubbles may have been present in the equipment. This would have a large effect on the system compliance and would result in the calculated dP/dV-related re-values being significantly larger than the theoretical values. It seems unrealistic that the system compliance alone could account for re differences of factors between 2.5 and 3. However, the calculated re values should be used in evaluating some of the downhole pulse tests, to determine the impact of assuming that the packer system responded as it did during the casing test.

Whatever the cause, the re value during testing may have been larger than was assumed. In instances that it might have been larger, the wellbore storage effect was underestimated, and the response of the geologic medium would likely have been underestimated.

6. TESTING AND INTERPRETATION EXAMPLES

The purpose of this section is to present and discuss selected examples from the Oberbauen hydrogeologic testing program. The examples are representative of the testing techniques used and interpretation methods applied to arrive at the results reported in the interval reports and in this final field report. The three examples selected and their corresponding Appendix and NIB reference are:

Borehole	Depth	Test Type	Appendix	NIB
HVB	48.6D	Screening	A6	88-02,B
HGB	55.5D1	Detailed	B4	88-03,H
SA	311.0D	Detailed	C8	88-04,D

6.1 HVB/48.6D (Screening Test)

The first example was chosen for five reasons: First, it demonstrates the type of activities done during the screening tests in both the HVB and HGB boreholes. Second, it illustrates the importance of borehole history when testing relatively tight rocks. Third, it shows the typical bottomhole response that occurred throughout most of the HVB testing. Fourth, it illustrates the packer pressure response without a constant pressure source at surface. Fifth, it documents the non-response of the interval when the bottomhole zone was overpressured.

This was the second screening interval to be tested after the 100 m vertical borehole drilling had been completed. The purpose of testing was to determine if there was permeability in this section of the rock that warranted further detailed testing.

6.1.1 Interval characteristics

Drilling was done continuously without any reported fluid losses or drilling problems. Core recovery for the zone was 100 percent. The core of the drilled Valanginian Marl had fractures with widths from 1 to 15 mm that were either filled or partly filled. RQD was 25 to 100 percent. The caliper log indicated a relatively smooth in-gauge borehole diameter of 96 mm except for two peaks of 106 mm at 47 and 53 m. Uncorrected neutron log, porosity varied from 8 percent to 27 percent. Some separation between shallow and deep resistivity occurred between 44 and 48 m indicating the possibility of fluid invasion.

The interval was tested with a 20.0 m double packer straddle at a depth of 38.5 to 58.6 m. The interval pressure transducer was at a depth of 36.1 m. The downhole shut-in volume below the FAV was estimated at about 110 litres.

6.1.2 Borehole history

Drilling and other borehole activities opposite the interval lasted about 6.5 days prior to testing during which time the fluid level in the borehole was commonly above the static level for the interval. The three principal activities that comprise the interval history, their time length, and the estimated pressures at the interval transducer depth were:

	Activity	Length (hr)	Pressure (kPa)
1.	Drilling	58	473 to 507
2.	Logging	55	460
3.	HVB/28.6D Testing	38	467 to 208
TOTAL		141	

Figure 6.1 summarizes the borehole history pressures estimated for the interval prior to testing as well as the discretized pressure history used for some of the analysis simulations.

6.1.3 Interval responses

Figure 6.2 illustrates the testing done and the pressure responses of the interval, annulus and bottomhole zones. The annulus pressure was relatively stable with fluctuations of about 2 kPa. The average annulus pressure was about 457 kPa. The bottomhole pressure dropped by 211 kPa to 273 kPa and was still declining at about 5 kPa/hr at the end of testing. Temporary changes in the bottomhole pressure were induced as described below.

Testing consisted of 8 events that lasted a total of about 36 hours. The events were:

1.	Inflation	INF
2.	Compliance	COM
3.	Shut-in recovery	Psr
4.	Pulse injection 1	Pi1
5.	Slug injection 1	Si1
6.	Pressure recovery 1	Pr1
7.	Slug withdrawal 1	Sw1
8.	Pressure recovery 2	Pr2

The testing event times, respective durations, and start and end temperatures and pressures are given in Table 6.1. Figure 6.3 shows the temperature response. Temperatures at sensor depth varied from about 16°C to about 17°C, within expected tolerance. The surface probe temperature remained at about 20°C, reflecting tunnel environmental conditions.

Figure 6.4 illustrates the packer inflation pressure throughout the testing. Packer pressure was initially increased to about 63 bars at the surface. It was shut-in at surface and dropped about 17 bars during testing. The drop in pressure was due to continued expansion of the packers.

Figure 6.2 illustrates that bottomhole pressure was increased on two separate occasions during testing at Points A to B, and Points C to D to E. No change occurred in the interval pressure. This shows that there was no communication between the interval and the bottomhole zone.

The interval pressure response was consistent during testing (Figure 6.5). Inflation was followed by a 131 minute compliance period during which time the fluid level remained constant at about 473 kPa. The FAV was closed at the end of compliance. The pressure dropped continuously during the Psr event that lasted 67 minutes and was terminated early. The pressure was still decreasing at the rate of about 90 kPa/hr when the initial pulse test began.

The first pulse test (Pi1) was done by overpressurizing the system at the surface with about 1 bar through the lines to the manifold board. Once the overpressure was attained on the flow control board, the downhole FAV was opened and closed. In this instance, the FAV was open for 5 seconds. The initial pressure of 470 kPa was well documented. The planned overpressure had been higher, but the hydraulic connection to the source of the 5 bar overpressure was closed prior to opening the FAV. The pressure fell when the FAV was opened and the net overpressure to the total system volume was about 1 bar.

The FAV was closed and the pressure falloff lasted 111 minutes. The pressure decayed and at the end of Pi1 was trending to a similar value to the one at the end of the Psr. As shown in Figure 6.5, the P2 response at the end of Pi1 was similar to the end of the preceeding Psr event.

The results of the Pi1 and Psr events suggested that borehole history was likely still dominating the response at this time and a decision was made to see if the interval would flow. The fluid level in the tubing was topped up and the FAV opened. The interval pressure declined by less than 0.5 kPa during the 13 minute slug injection event suggesting that it was not permeable enough for flow. The FAV was then shut-in for about 27 hours during which time the pressure decreased by 220 kPa.

The fluid level in the tubing was lowered and a slug withdrawal test began with a P2 pressure of

166 kPa. The flow lasted 72 minutes during which time the pressure increased by about 2 kPa confirming the relatively low permeability of the interval. Subsequently, the FAV was closed and the pressure recovered by about 45 kPa to a final pressure of 212 kPa at the end of about 220 minutes of shut-in. The testing was terminated recognizing that there was no permeable zone for testing at the detailed stage.

6.1.4 Analysis approach

Initial indications at the time of the first screening test (HVB/28.6D) were that a more permeable zone existed below the bottom packer. Testing in the HVB/48.6D zone demonstrated that this permeable zone was still below the bottom packer. This was substantiated by both screening tests having similar bottomhole responses. This was important to recognize since the project's emphasis was on the more permeable zones, not the tighter ones.

Temperatures recorded at the location of the sensor carrier was between 16^{o}C and 17^{o}C. Temperature was likely constant at this location during the entire test sequence and therefore, it was assumed that the temperature in the interval also remained constant. Therefore, no temperature effect was included in the analysis of the data.

The pre-test borehole pressure history shown in Figure 6.1 was determined and translated into equivalent pressures at the P2 transducer depth accounting for a changing drilling mud specific gravity and atmospheric pressure.

At the beginning, the analyses of the QLR report were reviewed. Field analysis of Pi1 had been done using GLIMPSE. The data fell between simulations with hydraulic conductivity ranging from 1e-11 to 1e-10 m/s at a storativity of 1e-5 and a static pressure of 370 kPa, the value just prior to beginning the pulse event. The data were influenced by the continuing transient pressure at the end of the event. The Horner analysis of Pr1 was not likely accurate since infinite acting radial flow conditions were not achieved during the slug flow period. It gave a hydraulic conductivity value of about 2e-11 m/s. This range of values provided the starting point for the interval report analyses using the GLIMPSE model.

The GLIMPSE analysis used to prepare the Interval Report was confined to attempts to bound the test data using a wellbore model. A major difficulty in doing this analysis, as was true for all of the HVB results, was determining the appropriate value of static pressure to be used for the interval. At this point in the testing, there was no documented value of static pressure at the site. The initial analysis used the extrapolated Pr1 end pressure as a value of static. Figure 6.6 illustrates the results that come closest to bounding the data. In general, however, there was no good result achieved with this high a static pressure with hydraulic conductivity values between 1e-12 and 1e-11 m/s and storativity in the range of 1e-7 to 1e-3.

Figure 6.7 shows that the data for most of the events was well bounded with simulations having hydraulic conductivities from 6e-12 to about 2e-11 m/s at a storativity of 1e-3 and at a static pressure of 130 kPa.

Figure 6.8 illustrates the influence that borehole history has had on the interval response and how misleading the static pressures determined from the field analyses, which did not include borehole history, can be, as compared with the model.

6.1.5 Interpretation conclusions

The interval response was relatively well bounded including the borehole history pressure estimated for events that lasted about 6.5 days prior to testing. Borehole history pressures are well documented. The extent to which they extended into the formation is not known.

Many attempts were made at bounding the test data using higher static pressures. The static pressure in the interval is not considered to be well documented, but is likely in the range of 100 to 150 kPa. Such a low pressure range suggests the possibility that the rock may not have been water saturated prior to testing. There was no way of testing this relatively tight formation to determine if that was the case.

In contrast, attempts at bounding were successful using relatively high values of S and low values of static pressure. The early time responses during the shut-in periods suggest a higher S condition, or perhaps a negative skin effect or fractures. Compliance effects, as noted in the Casing Test 2 (Section 5.2.4), could explain the high values of wellbore storage required. S values above $1e^{-3}$ could not be justified.

The static pressure of 130 to 215 kPa is equivalent to a hydraulic head elevation about 460 to 469 m(asl), compared to the tunnel floor and Uri Lake level elevations of about 494 and 433 m(asl), respectively.

6.2. HGB/55.5D1 Detailed Test

The second example was chosen for three reasons. First, it illustrates the types of activities done during the detailed testing in both the HVB and HGB boreholes. Second, it demonstrates that changes can occur in the near wellbore characteristics during testing. Third, it shows the hydraulics associated with the use of the HVT surface shut-in volume.

This was the third detailed interval to be tested in screening interval HGB/62.5. The testing was conducted to isolate what was believed to be the most permeable section of the screening interval.

This zone was subsequently retested (HGB/55.5D2) and then further investigation related to gas mobility in the Valanginian Marl was done to complete testing in the borehole (HGB/55.5D-GAS).

6.2.1 Interval characteristics

Drilling was done continuously without any reported fluid losses or drilling problems. Core recovery for the zone was 100 percent. The rock was grey marlstone with four open fractures in the lower part with the aperture of 5 to 10 mm. RQD was 80 to 100. The caliper log varied between 96 and 100 mm. The uncorrected neutron log porosity varied from 6 percent to 11 percent. A moderate separation between the deep and shallow resistivities occurred in the lower part of the interval suggesting the possibility of fluid invasion.

The interval was tested with a 6.6 m double packer straddle. It extended from about 52.2 to 58.8 m along the length of the 100 m inclined borehole. The interval pressure transducer was at 49.8 m, at a true depth of about 32 m. The downhole shut-in volume below the FAV was about 50 litres. The shut-in volume which included the tubing string and the NAGRA HVT was about 900 litres.

6.2.2 Borehole history

Drilling and other borehole activities opposite the interval lasted about 14 days prior to testing during which time the fluid level in the borehole was commonly above the static level for the interval. The specific activities that comprise the interval history, their time length, and the estimated pressures opposite the interval were:

	Activity	Length (hr)	Pressure (kPa)
1.	Drilling	57	466
2.	Logging	40	466 to 278
3.	HGB/82.5D Screening	35	467
4.	HGB/62.5D Screening	21	1160 to 215
5.	HGB/42.5D Screening	12	464 to 215
6.	HGB/Change Straddle	10	463 to 363
7.	HGB/76.3D Detailed	9	470 to 459
8.	HGB/83.3D Detailed	101	472 to 460
9.	HGB/68.7D Detailed	24	468
10.	HGB/62.1D Detailed	18	468
11.	Move to HGB/55.5D1	1	466 to 460
	TOTAL	328	

Figure 6.9 summarizes the borehole history pressures estimated for the interval prior to testing as well as the discretized pressure history used for some of the analysis simulations.

6.2.3 Interval responses

Figure 6.10 illustrates the testing done and the pressure responses of the interval, annulus and bottomhole zones. The annulus pressure did not change, remaining at about 465 kPa throughout. The bottomhole pressure dropped by about 360 kPa to about 120 kPa and was still declining at the end of testing.

Testing consisted of 10 events that lasted a total of about 20 hours. The events were:

1.	Inflation	INF
2.	Compliance	COM
3.	Shut-in recovery	Psr
4.	Pulse injection 1	Pi1
5.	Pulse injection 2 (Tank)	Pi2
6.	Pressure recovery 1	Pr1
7.	Slug injection 1	Si1
8.	Pressure recovery 2	Pr2
9.	Slug withdrawal 1	Sw1
10.	Pressure recovery 3	Pr3

The testing event times, respective durations, and start end temperatures and pressures are given in Table 6.2. Figure 6.11 shows the temperature response. Temperatures at sensor depth varied from 15.8°C to 16.8°C within expected tolerance. The surface probe temperature was about 20°C reflecting tunnel environmental conditions.

Figure 6.12 illustrates the packer inflation pressure throughout the testing. Packer pressure was maintained with the constant pressure nitrogen source at about 50 bars at the surface. It dropped about 100 kPa during testing due to the limited sensitivity of the pressure regulator.

The interval pressure response was not consistent during testing (Figure 6.13). The response during compliance and the Psr events was slower than the subsequent events. The two following pulse tests responded more quickly than the compliance and Psr events, but less quickly than the final flow and recovery periods.

Inflation was followed by the compliance period during which time there was little change in the fluid level on the tubing. The FAV was closed at the end of compliance and the pressure dropped continuously at a relatively consistent rate during the Psr event that lasted about 6.6 hours. The pressure was still decreasing when the initial pulse test began.

The first pulse test was done by overpressurizing the system at the surface with about 5 bars using tap water. Once the overpressure was attained on the flow control board, the downhole FAV was opened and closed. In this instance, the FAV was open for about 13 seconds while the initial pressure was documented. Then the FAV was closed and the pressure falloff lasted about 76 minutes. Surprisingly, within about 3 minutes, the pressure had decayed to the value at the end of the Psr and continued to drop. It levelled off after decreasing by an additional 100 kPa.

A second pulse test (PI2) was done to confirm the surprisingly low end pressure during Pi1. This time the tank was used as an additional shut-in volume. The dynamics of the hydraulic system involving the tank are illustrated in Figure 6.10. The pressure decayed to about 396 kPa within about 8 minutes and then stayed at that pressure. However, when the downhole valve was closed for the following Pr1 event, the pressure decayed an additional 144 kPa.

The stabilization of the pressure at 396 kPa illustrates the suction effect associated with the surface HVT. This pressure represents an induced hydraulic head under static conditions of about 7 m below the annulus level and about 9 to 10 m below the top of the HVT located in the control room. Therefore, there was an artificially imposed pressure condition associated with the use of the tank system. This dynamics, however, is really only manifest when the permeability of the interval tested is high enough to allow relatively rapid responses.

The results of the Pr1 event confirmed the Pi1 pressure response. This suggested that there had been a change in the near-wellbore conditions as a result of the Pi1 overpressure. Further testing confirmed that the static pressure was below that indicated from the Psr event.

Testing continued with a slug injection and shut-in recovery event following Pr1. The fluid level fell about 4.5 m (true vertical depth) in the tubing during the slug injection test, unlike during compliance when it had remained at the top of the tubing. This further documented the change and suspected unplugging that had occurred at the beginning of the Pi1 event. The Pr1 shut-in response decayed by about 150 kPa over the next 135 min to a final pressure of about 274 kPa. At this time, the final slug withdrawal and buildup period testing began. The fluid level rose about 2.7 m true height during the two hour flow. Subsequently, it recovered about 70 kPa to a final shut-in pressure of 239 kPa.

6.2.4 Analysis approach

Results of the events following Pi2 were all similar. They indicated, first, that there was flow potential from the interval, and second, that the estimated static pressure for the zone was in the range of 240 to 250 kPa. These results compare to the no flow conditions suggested from the compliance period and the end pressure range of about 280 to 300 kPa from the Psr event. The borehole damage or plugging near the wellbore appears to have been bypassed as a result of the Pi1 initial overpressure. This type of response was similar to that seen during the initial screening test (HGB/62.5D), which included this interval.

Initial indications at the time of testing were that the HGB/55.5D interval was the zone that contributed to the HGB/62.5D screening test response. This was based on the HGB/55.5D results and the occurrence of open fractures in the core plus the relatively slow response of the two other detailed interval tests done in the screening interval (HGB/68.7D and HGB/62.1D).

Temperature recorded at the location of the sensor carrier was between about 16°C and 17°C. Temperature was likely constant at this location during the entire test sequence and therefore, it was assumed that the temperature in the interval also remained constant. Therefore, no temperature effect was included in the analysis of the data.

The pre-test borehole pressure history shown in Figure 6.9 was determined and translated into equivalent pressures at the P2 transducer depth accounting for the angle of the borehole and atmospheric pressure.

At the beginning, the analyses of the QLR report were reviewed to determine if the boundary conditions for the single event analysis were met. Analysis of Pi1 was not accurate since the initial boundary assumptions were violated. Pi2 analysis was not valid due to the artificial pressure condition associated with the tank. Therefore, neither of the pulse test events could strictly be relied upon to provide a reasonable value for the zone hydraulic conductivity.

Log-log diagnostic plots similar to those used in the petroleum industry showed that Si1-Pr2 events did not attain radial flow. However, the log-log plots of the Sw1-Pr3 events suggested that radial flow conditions were reached in both events. Therefore, the results of the Horner analysis of the Sw1-Pr3 events which yielded a hydraulic conductivity of between 3e-9 to 5e-9 m/s were more representative of the interval conditions than the Si1-Pr2 conditions.

Analysis of the zone response had to take into account that there was a change in the near wellbore conditions during testing. In other words, there had been a change in the skin effect in the zone. Once the apparent plugging was overcome, however, it did not reappear. Therefore, the analysis of the zone response was separated into the three sets of test responses. The first was for compliance and Psr events including borehole history pressures. The second was for these events plus the first pulse test events, including borehole history. The third was for the rest of the testing excluding borehole history.

The analysis approach used to prepare the Interval Report was an attempt to bound the test data using the GLIMPSE wellbore model. Initial runs were carried out to determine the effect of the pre-test history on the compliance and Psr events.

Figure 6.14 illustrates bounding analyses varying both storativity and static pressure. This figure illustrates that a hydraulic conductivity of 3e-10 m/s, the shape of the responses are not similar to the data response even when the static pressure was varied. The early time data response was slower than the simulations at a hydraulic conductivity value of 3e-10 m/s. This suggests that fine tuning of the bounding would have been achieved using a value of less than 3e-10 m/s. No additional effort was made to characterize the temporary skin value since it was of lesser importance than characterizing the following events.

The second step was to assign both the COM and Psr events constant pressures and to attempt to bound the Pi1 including borehole history (Figures 6.15 and 6.16). The results of these two plots show that the data can be bounded using a static pressure in the vicinity of about 130 kPa to 150 kPa, a K-value in the range of 3e-10 to 3e-8 m/s, and an S-value in the order of 1e-6 to 1e-5.

The third step was to assign both Pi1 and Pi2 constant pressures and attempt to bound only the responses of the flow and recovery events. The set-up for doing this is shown in Figure 6.17. Figures 6.18 and 6.19 show the bounding that was obtained for the last five events including borehole history.

As a final step, all events prior to Pi1 were dropped, assuming that there was no borehole history effect and that the early testing did not affect the interval that was finally being tested. The results of this are shown in Figure 6.20. This bounding was achieved with about the same range of hydraulic conductivity. However, a static value of about 250 kPa was required, compared to the value of 150 kPa that was used with borehole history included.

6.2.5 Interpretation conclusions

The response of HGB/55.5D, compared with HGB/68.7D and HGB/62.1D, suggests that it was the major contributing interval to the screening test, HGB/62.5D.

Borehole history pressures are well documented. The extent to which they extended into the formation is not known. The concept of an initial tighter skin effect is considered reasonable, based simply on the dramatic change in pressure response pattern during the testing. The skin created by previous borehole activities seen and broken in HGB/62.5D, recurred when testing this interval.

The static pressure in the interval is about 250 kPa, based on two assumptions; first, that the borehole history did not influence the response; and second, that once the skin effect was removed, the true formation parameters caused the interval response. Otherwise, the bounding including borehole history results in a much lower static. Either a skin effect or other factors caused the interval response pattern to change.

The static pressure value of 250 kPa is equivalent to a hydraulic head elevation of 472 m(asl), compared to the tunnel floor and Uri Lake elevations of 494 m and 433 m(asl), respectively.

Bounding was achieved using a K-value of between $1e^{-9}$ m/s and $5e^{-9}$ m/s in either the history or no-history situation, with S-values in the range of $1e^{-5}$ to $1e^{-3}$. COM and Psr conditions reflecting the apparent skin zone hydraulic conductivity values are lower by at least an order of magnitude compared to the final two flow and buildup periods.

6.3 SA/311.0D Detailed Test

The third example was chosen for four reasons. First, it was the deepest zone tested on the project. Second, it illustrates the types of activities done to document the pressure/head at this depth. Third, it shows the type of response that is typical of a zone with moderate permeability. Finally, it illustrates that only a limited amount of drawdown needs to be used to test this type of interval which will flow, albeit at a rate of less than 0.1 litres per minute.

This was the second interval to be tested in the 350 m SA vertical borehole after the drilling had been completed to total depth. The purpose of testing was first, to document the pressure in a permeable zone near the bottom of the hole, and second, to determine the hydraulic characteristics of the Valanginian limestone in the vicinity of the Tertiary contact. The testing to determine a pressure/head in the bottom of the borehole had been targetted at one of three zones, the SA/298.0D interval, the SA/311.0D interval, or in the lower part of the borehole in the Tertiary rock. The SA/298.0D interval tested first was not permeable enough to document a pressure/head. The Tertiary test was not needed because the SA/311.0D bottomhole pressure response provided enough information for the bottomhole section.

6.3.1 Interval characteristics

Drilling was done continuously without any reported fluid losses or drilling problems. Core recovery for the zone was 100 percent. The rock consists of Valanginian limestone immediately above the contact with the Tertiary shales. Two open fractures were at 307 and 309 m. Others were infilled or closed. RQD was 50 to 100 percent. The results of the 8-arm caliper log were not available at the time of testing. The uncorrected neutron log porosity varied from 2 percent to 11 percent with an average of about 4 percent. Little separation was seen between the deep and shallow resistivities suggesting there was only small fluid invasion.

The interval was tested with a 15.1 m double packer straddle at a depth of 303.5 to 318.6 m. The interval pressure transducer was at a depth of 301.0 m. The downhole shut-in volume below the FAV was about 80 litres.

6.3.2 Borehole history

Drilling and other borehole activities opposite the interval lasted about 5.5 days prior to testing during which time the fluid level in the borehole was commonly above the static level for the interval. The three principal activities that comprise the interval's history, their time length and the estimated pressure opposite the interval were:

Activity	Length (hr)	Pressure (kPa)
1. Drilling	49	3084
2. Logging	48	3084
3. SA/298.0D Testing	35	3084 to 2526
TOTAL	132	

Figure 6.21 summarizes the borehole history pressures estimated for the interval prior to testing as well as the discretized pressure history used for some of the analysis simulations.

6.3.3 Interval responses

Figure 6.22 illustrates the testing done and the pressure responses of the interval, annulus and bottomhole zones. The annulus pressure increased by about 80 kPa at a relatively consistent rate during testing with a final pressure of about 2947 kPa. It was still declining at a rate of about 3 kPa/hr at the end of testing. The bottomhole pressure dropped by about 400 kPa to about 2823 kPa and was still declining at about 2 kPa/hr at the end of testing.

Testing consisted of 10 events that lasted a total of about 25 hours. The events were:

1. Inflation INF
2. Compliance COM
3. Shut-in recovery Psr
4. Pulse injection 1 Pi1
5. Slug withdrawal 1 Sw1
6. Pressure recovery 1 Pr1

The testing event times, respective durations, and start and end temperatures and pressures are given in Table 6.3. Figure 6.23 shows the temperature response. Temperatures at sensor depth varied from about 23°C to about 24°C, within expected tolerance. The surface probe temperature varied between about 20°C and 22°C, reflecting tunnel environmental conditions.

Figure 6.24 illustrates the packer inflation pressure throughout the testing. Packer pressure was maintained with the constant pressure nitrogen source at about 50 bars at the surface. It increased about 350 kPa during testing possibly due to borehole hydrostatic loadings or packer compression.

The interval pressure response was consistent during testing (Figure 6.25). Inflation was followed by a 70 minute compliance period during which time the fluid level dropped by about 4 m in the tubing. The FAV was closed at the end of compliance. The pressure dropped continuously during the Psr event that lasted about 5 hours. The pressure was still decreasing at about 3 kPa/hr when the initial pulse test began.

The first pulse test was done by overpressurizing the system at the surface with about 13 bars. Once the overpressure was attained on the flow control board, the downhole FAV was opened and closed. In this instance, the FAV was open for about 22 seconds while the initial pressure was documented. The FAV was then closed and the pressure falloff lasted about 85 minutes. The pressure decayed and was trending to the same value as at the end of the Psr event.

The results of the Pi1 and Psr events confirmed the formation pressure and suggested that the interval was permeable enough to flow. The fluid level in the tubing was lowered and the slug withdrawal testing began with a pressure of about 2230 kPa. The flow lasted 250 minutes during which time about 12 m of fluid rose into the tubing string and the final flowing pressure was 2357 kPa. Subsequently, the FAV was closed and the pressure recovered by 130 kPa in the first 38 minutes of shut-in. It then increased more slowly to a final shut-in pressure of about 2505 kPa at the end of about 13 hours. The testing was terminated with consistent pressures obtained for each shut-in recovery event.

6.3.4 Analysis approach

Initial indications at the time of testing were that SA/311.0D interval was the zone that contributed to the bottomhole response during the SA/298.0D test previously. This was further suggested by the relatively slow bottomhole response during the SA/311.0D test. Therefore, it appears that the most permeable zone near the bottom of the borehole was the SA/311.0D interval.

Temperature recorded at the location of the sensor carrier was between 23^{o}C and 24^{o}C. Temperature was likely constant at this location during the entire test sequence and therefore it was assumed that the temperature in the interval also remained constant. Therefore, no temperature effect was included in the analysis of the data.

The pre-test borehole pressure history shown in Figure 6.21 was determined and translated into equivalent pressures at the P2 transducer depth accounting for a documented drilling mud specific gravity of about 1.006 and atmospheric pressure.

In the beginning, the analyses of the QLR were reviewed to determine if the boundary conditions for the single event analysis were met. Cooper analysis of Pi1 was not strictly valid since the FAV was open for about 22 seconds and the zone response thereafter was relatively fast. Therefore, the conditions at the start of the test were not correct.

Log-log diagnostic plots showed that the SW1 event did not attain infinite-acting radial flow, but the subsequent Pr1 event did. Therefore, the results of the Horner analysis of the Sw1-Pr1 events which yielded a hydraulic conductivity of 4e-9 m/s may not be accurate.

The analysis approach used to prepare the Interval Report was to attempt to bound the test data using the GLIMPSE wellbore model. The first step was to use the results from the Pi1 analysis Figure 6.26 and also include borehole history. Ranges of 1e-11 to 1e-10 m/s were not permeable enough. Figures 6.27, 6.28 and 6.29 show the data was bounded well over the range of 1e-7 to 1e-3 for storativity and for pressures from 2400 to 2450 kPa at a hydraulic conductivity value of 1e-9 m/s.

6.3.5 Interpretation conclusions

The interval response was relatively well bounded including the borehole history pressure estimated for events that lasted about 5.5 days prior to testing. Borehole history pressures are well documented. The extent to which they extended into the formation is not known.

The static pressure in the interval is about 2450 kPa. Bounding was achieved using a K-value of between 1e-9 m/s and 5e-9 m/s with borehole history, with S-values in the range of 1e-7 to 1e-3.

Bounding of the flow during the COM event was done with a K-value between 1e-9 and 5e-9 m/s (Figures 6.29 and 6.30). However, these values simulate responses that at early time are faster than the Psr and Pi1 events. The fact that the simulations and data do not match well both at early and late time suggest the wellbore storage conditions are incorrect, a skin effect may be present or other model conditions were not exactly as simulated. In general, however, the data have been well bounded for the entire testing within a relatively well documented range of hydraulic conductivity and static pressure values.

The static pressure of 2450 kPa is equivalent to a hydraulic head elevation of about 431 m(asl), compared to a Uri Lake level of about 433 m(asl).

7. RESULTS OF THE HVB

The purpose of this section is to summarize the testing that was done in the first of the boreholes drilled and tested, the 100 m vertical borehole referred to in the NAGRA planning documents as HVB. The rationale for design of the borehole testing is presented followed by a discussion of the results from the testing.

Drilling, including setting the surface casing, took a total of 5 days to complete to a total depth of 100.2 m below the reference point. The entire borehole was cored and logging of the core was done on-site as drilling progressed. Drilling was followed by about 50 hours of geophysical logging. Preliminary field interpretations were made as the results were available. Testing began on 28 May, 1987 and lasted for about 12 days until 09 June, 1987. A total of ten intervals were tested, four as screening-type and six as detailed-type zones. Summaries of the HVB tests are given in Appendix A as follows

Test Interval	Test Type	Appendix Number
HVB/25.6D	Detailed	A1
HVB/28.6D	Screening	A2
HVB/32.0D	Detailed	A3
HVB/42.5D	Detailed	A4
HVB/47.6D	Detailed	A5
HVB/48.6D	Screening	A6
HVB/52.7D	Detailed	A7
HVB/69.6D	Screening	A8
HVB/74.5D	Detailed	A9
HVB/78.9D	Screening	A10

7.1 Testing Plan and Rationale

NAGRA (NIB 88-25) prepared a summary of the rationale and testing plan information to explain and document the decisions that were made as to how and what sections to test in the borehole. This reference provides the basis for this section of the report.

The geology, geophysics and drilling information was compiled and discussed in order to prepare the plan for the borehole testing program. The testing plan for the shallow 100 m boreholes involved two stages, screening and detailed tests. Between three and five screening tests were planned to completely cover the entire sequence from the base of the casing at about 20 m depth to total depth. The detailed testing plan was then developed based on the results of the screening tests. Meetings of most persons contributing to and involved in hydraulic testing were held periodically on-site to further refine the testing plan and confirm the suitability of the packer seats.

7.1.1 Geology

The geologic data reviewed prior to selecting the zones to be tested included core recovery, lithology, structural details such as shear zones and fracture types and spacing, and RQD. Anticipated shear zones were not clearly definable from the core. The entire borehole was relatively homogeneous from both a lithologic and structural view point. Specific zones where open fractures occurred that could be water-bearing were from 24 to 40 m, 44 to 57 m, and 67 to 79 m. The RQD values indicated good packer seats over six zones at 23 to 25 m, 38 to 40 m, 43 to 45 m, 58 to 60 m, 68 to 75 m, and 78 to 85 m.

7.1.2 Geophysical data

Geophysical information for the entire borehole included temperature, salinity, caliper, self-potential (SP) and gamma logs run by INTERGEO A.G., petrophysical logs consisting of resistivity, density, neutron porosity, sonic, spectral gamma ray (kalium, uranium, thorium) and dipmeter run by British Plaster Board (BPB), and the Scanning Acoustic Borehole Imaging System (SABIS) televiewer run by Westfaelische Bergbaukasse (WBK). Both the salinity and temperature logs appeared to have been affected by a mixing of fluid used to top-up the borehole fluid level and the final recirculation event after drilling was completed. The caliper log was generally consistent with the gamma log with washouts opposite zones of higher clay content.

Caliper effects had not been compensated for in the field logs available prior to testing and were evident in the SP, density, neutron, and sonic logs. Resistivity logs showed possible invasion of drilling fluid from 78 to 100 m. Changes in sonic velocity reflecting carbonate content occurred at 53 and 74 m. The high resolution dipmeter showed zones with increased carbonate content at 24 to 26 m, 49 m, 53 m, 62 to 63 m, 72 to 73 m, and at 88 m. The sonic televiewer log confirmed the packer seats determined from the core and RQD data.

7.1.3 Drilling and other borehole information

No fluid losses were observed during the time the borehole was drilled or during the geophysical logging.

7.1.4 Screening test intervals

The excellent core recovery, high RQD, lack of open discontinuities seen in either the geology or geophysics and lack of any fluid loss in the borehole suggested the rock would be relatively similar and have a low permeability throughout. Four screening zones were selected to determine if any part of the borehole had sufficient permeability to warrant sampling during the detailed testing. The screening plan decided upon just prior to the beginning of testing was for a straddle length of about 20 m with zones tested from about 20 to 40 m, 40 to 60 m, 60 to 80 m, and 80 to 100 m (Table 7.1). Selection of the 20 m straddle length allowed testing the entire borehole with 3 packer seats with the fourth and final bottomhole zone test done using the P1 line to surface with the same packer setting as the third screening test.

Four screening tests were performed (Table 7.1 and Figure 7.1). The first three done (HVB/28.6D, HVB/48.6D, and HVB/69.6D) were similar to the original plan. However, due to the interval fluid level being unexpectedly below rather than above the top of the borehole, not all the P1 hydraulic responses could be relied upon to be representative of the properties of the bottomhole interval tested.

The deepest screening test (HVB/78.9D) was done with a double packer rather than spend the time to run out and back into the borehole with a single packer configuration. The deepest possible straddle zone was from about 69 to 89 m. This lowest seat was selected considering the poor caliper log between 93 and 98 m, the packer length of about 0.9 m and the tail pipe length of about 2 m. This left only the bottom 10 m of the HVB borehole that was not actively tested. The P1 response of HVB/78.9D screening test gave some indication about the bottomhole section.

The planned sequence of testing during the screening phase was to consist of the following basic procedures:

1. Inflation,
2. Compliance,
3. Shut-in pressure recovery towards static (Psr),
4. Pulse injection/withdrawal depending on the Psr period response, first, using the downhole FAV and, if possible, a second pulse using the HVT,
5. Slug-type test if adequate conductivity,
6. Constant rate/pressure test if time permitted,
7. Shut-in recovery.

The water level in the tubing string dropped a few cm during the open period at the start of the pulse injection test in the first screening interval. This drop was not expected given the relatively low hydraulic conductivity of the zone. The valve was left open for 1/2 hour after the first Pi1 event to observe if this phenomenon was equipment related. It did not appear to be. Therefore, a decision was made to perform a slug-type event and this, plus the following shut-in recovery, were treated as a drill stem-type test. Testing sequences similar to this were repeated for the next two screening intervals (HVB/48.6D, HVB/69.6D). The testing activities of the HVB/48.6 D interval are described in detail in Section 6.1. The HVT surface shut-in volume was used for the second pulse injection test in the last screening interval (HVB/78.9D).

7.1.5 Detailed test intervals

The preliminary plan for detailed testing of the HVB was made during the final hours of the fourth screening test. The plan was left flexible in order to accommodate changes that would naturally occur as the results from the ongoing testing were discussed and their implications realized. Discussion of the screening test results and the background geologic and geophysical data was the basis for the preliminary plan. In particular, the correlation of packer pressure with interval pressure, the unexplained irregularities in the P1 response in part due to P1-to-surface line, the difference in pulse test and DST-derived hydraulic conductivity values, and the apparently higher hydraulic conductivity of the second screening interval, were features of the screening tests that influenced the detailed test plan. Additional time and effort had also been given to the available background geologic and geophysical data by this time. This also provided information relevant to selecting the shorter intervals for more detailed testing.

The preliminary plan consisted of the following program criteria:

1) Conduct a casing test to observe interval pressure responses as a function of equipment compliance, specifically packer pressure changes,

2) Investigate the possibility of using a constant packer pressure source,

3) Close the P1 line-to-surface to remove the possibility of air in the line affecting the bottomhole response,

4) Concentrate on the 40 to 60 m zone of apparent higher hydraulic conductivity for detailed testing,

5) Conduct a matrix rock test using a smaller straddle than that from the screening tests,

6) Bound the static pressure above and below the matrix rock test zone by testing above and below it,

7) Use higher pulse test overpressures than in the screening tests for better responses,

8) Re-test a screening test interval to check for transient behaviour of rock hydraulic properties,

9) Use a 5 m straddle since it conveniently covers the 40 to 60 m zone and at the same time fits the good packer seats in this depth, allows matrix rock environment testing with good packer seats, and is less than the minimum spacing of permeable features based on earlier geologic predictions.

The proposed plan based on the above criteria for detailed testing is given in Table 7.1. The plan consisted of testing every 5 m section from 40 to 65 m and then to re-test the 40 to 60 m screening test interval with a 20 m straddle. The actual testing is shown on Table 7.1 and Figure 7.1.

The testing was started and the first three detailed tests were conducted according to the plan. At that point, additional consideration of the responses and geology and geophysics of the other screening test zones suggested first, that the 20 to 40 m of uncased borehole could be as or more permeable than the 40 to 60 m interval, and that the 70 to 80 m zone could have hydraulic conductivity on the order of 1e-11 m/s.

Accordingly, the final three detailed tests in the borehole were done in the 70 to 80 m and 20 to 40 m depths opposite washout zones, given a possible correlation between poor rock quality and permeability. The re-test of the 40 to 60 m interval and the matrix bounding tests were dropped for the above substitutions.

A constant packer pressure system was implemented for the remainder of the testing based on the test done in the borehole casing at the start of the detailed testing. The P1 line-to-surface valve was closed prior to the start of testing. Changes in the fluid level in the P1 line did not influence the bottomhole pressure response.

A standard approach was used for monitoring of inflation, compliance and the initial pulse events. Thereafter, the sequence of events that was followed in each detailed interval was guided by the interval's transient pressure response. Intervals HVB/42.5D, HVB/74.5D and HVB/32.5D were terminated after only one pulse test due to their relatively slow response and low hydraulic conductivity. Intervals HVB/47.6D, HVA/52.7D and HVB/25.6D included a second pulse test done with the surface HVT. Injection pumping equipment and testing procedures were checked and evaluated by conducting two constant rate and one constant pressure events in intervals HVB/47.6D and HVB/25.6D, respectively.

7.2 Hydrogeologic Testing Results

Table 7.2 and Figures 7.2 through 7.5 illustrate the results of the analysis done on the 10 double packer intervals tested in the HVB borehole.

Preliminary analyses were done in the field. A Quick Look Report was prepared illustrating these results during and shortly after completion of testing in each interval. This was described in Section 4.2. The results described in this section are based on the interval report (IR) analysis results which incorporated the use of the borehole simulation model, GLIMPSE, described in Section 4.1.2. As such, the results should be considered as a first interpretation and are not considered representative or indicative of the conditions such as skin effect or fracture flow that may have been present at the time of testing. Rather, they illustrate values to be compared with a model assuming a homogeneous, isotropic medium with radial flow and wellbore storage conditions.

The bounding approach used in most of the analyses has resulted in ranges of hydraulic parameter of values in many cases. The individual analyses found in NIB 88-02 should be referred to for a more complete understanding of the sensitivity of the bounding to variations in parameter values.

7.2.1 Borehole history

The pre-test activities that took place prior to any testing in the borehole lasted about seven days during which time the fluid level was at or near the top of the borehole. This means that the intervals tested were subject to inflow conditions and higher pressures than in-situ conditions. The length of time that these generally higher pressures lasted varied from about seven days in the case of the first screening test, HVB/28.6D to about 17 days in the case of the final detailed test, HVB/32.5D.

The extent of the overpressure is uncertain. The hydraulic conductivities of the rock tested in the borehole was so low that no representative static pressure was able to be determined in any interval. It is evident, however, from both the interval responses and the bottomhole pressure responses from the detailed test events that the formation fluid levels are below the top of the borehole.

Figure 7.1 illustrates each interval's borehole history arising from the influence of imposed pressures in the annulus, bottomhole and interval zones during prior testing. This is referred to as the interval testing pressure dependency.

7.2.2. Formation static pressure and hydraulic head

All pressure data for both the intervals tested and the bottomhole zones were reviewed prior to beginning the field report analyses. The purpose of this review was to determine if there were any justifiable values that could be used as bounding values in the approach used to assess the interval test results.

The analysis conducted to date has not resulted in any representative pressures for the intervals tested. Values used in the interval report analyses are given in Table 7.2. Figure 7.2 and Table 7.3 give the mid-interval pressure values used in the GLIMPSE analyses. End pressure values for the bottomhole zone tested are given in Table 7.4.

The borehole history effect and the low permeability of the intervals tested were the two factors that limited the static pressure sensitivity. A change of several hundred kPa had little change in the short-time response for hydraulic conductivity values in the range of 1e-13 m/s to 1e-10 m/s.

Hydraulic pressures were estimated for the bottomhole zones based on values at the end of all detailed tests. The range of hydraulic heads is from less than 451 m to less than 480 m(asl). Heads appeared to decrease with depth but this is not substantiated. The range in head values is not considered representative of individual intervals, but are maximum values generalized for the borehole. The values are for relatively large intervals and the influence of previous borehole history on the pressures used to calculate the heads has not been adequately quantified. Therefore, we do not consider that any of the pressures or hydraulic heads either for the intervals tested or in the bottomhole zones are necessarily representative of the original rock conditions.

7.2.3 Transmissivity and hydraulic conductivity

Figure 7.3 is a profile of transmissivity versus HVB borehole depth. All transmissivities are less than 1e-9 m2/s except for the HVB/69.6D screening test interval which was 2e-8 m2/s. Hydraulic conductivity values, assuming contribution is equally distributed throughout the interval tested, were less than 1e-10 m/s except for HVB/69.6D which was 1e-9 m/s to 1e-10 m/s. The higher value from HVB/69.6D interval was based on the flow rate required to match what occurred during the Sw1 event. Otherwise, the pulse and shut-in responses indicated lower values. This is described in more detail in Appendix A8.

The results from three of the four screening tests are consistent with the follow-up detailed tests in similar intervals. The HVB/25.6D and HVB/32.0D detailed tests had transmissivities of less than 1e-11 m2/s compared to the HVB/28.6D screening test upper limit of about 2e-10 m2/s.

The detailed HVB/42.5D rock matrix test done in the HVB/48.6D screening interval resulted in transmissivity values of less than 5e-13 m2/s.

The detailed HVB/42.5D rock matrix test done in the HVB/48.6D screening interval resulted in transmissivity and hydraulic conductivity values of less than 5e-13 m2/s and 1e-13 m/s, respectively.

This compares to the HVB/52.7D and 47.6D transmissivity of less than 5e-12 m2/s and 2e-11 to 5e-10 m2/s compared to the screening interval value of about 2e-11 to 4e-10 m2/s.

The single detailed test in the HVB/78.9D screening interval had a transmissivity about 1 order of magnitude lower than the screening test.

In contrast, the HVB/69.6D interval had a transmissivity value of less than $2e^{-08}$ m^2/s compared to the HVB/74.5D detailed interval of less than $5e^{-12}$ m^2/s. As described above, the upper limit for the HVB/69.6D test was based on bounding a single flow period result.

There is no trend evident from these results relative to depth in the borehole.

7.2.4 Specific storage

Figure 7.4 illustrates the ranges of specific storage determined using the bounding approach. In general, there is much less sensitivity in this parameter value than in transmissivity/hydraulic conductivity. Specific storage in most intervals ranged from $1e^{-7}$/m to $1e^{-4}$/m. No more certainty could be expected with the bounding approach used.

7.2.5 Temperature

The temperature profile for the borehole shown in Figure 7.5 indicates that temperatures ranged from about 16.5°C to about 17°C. The intervals above a depth of 40 m had temperatures about 0.5°C less than those below 40 m. Temperature profiles for the borehole should more realistically be based on the results of the geophysical logging.

8. RESULTS OF HGB

The purpose of this section is to summarize the testing that was done in the second of the boreholes drilled and tested, the 100 m inclined borehole referred to in the NAGRA planning documents as HGB. The rationale for design of the borehole testing is presented followed by a discussion of the results from the testing.

Drilling started on 10 June, 1987 and was completed seven days later at a total length of 100.8 m below the reference point. Surface casing was set to a depth of 20.1 m. The drilling was at an average angle of about 49° below horizontal. The actual measured depth at total length was 75.4 m based on the results of a deviation survey done after completion of testing.

The entire borehole was cored and logging of the core was done on-site as drilling progressed. Drilling was followed by about 40 hours of geophysical logging. Preliminary field interpretations were made as the results were available. Testing began on 19 June, 1987 and lasted for about 15 days until 03 July, 1987. A total of nine intervals were tested, three as screening-type and six as detailed-type tests. One of the detailed intervals was tested separately three times. The constant packer pressure system implemented for the detailed HVB testing was continued for the HGB testing. Summaries of the twelve HGB tests are given in Appendix B as follows:

Test Interval	Test Type	Appendix Number
HGB/23.1D	Detailed	B1
HGB/29.7D	Detailed	B2
HGB/42.5D	Screening	B3
HGB/55.5D1	Detailed	B4
HGB/55.5D2	Detailed	B5
HGB/55.5D-GAS	Detailed	B6

Test Interval	Test Type	Appendix Number
HGB/62.1D	Detailed	B7
HGB/62.5D	Screening	B8
HGB/68.7D	Detailed	B9
HGB/76.3D	Detailed	B10
HGB/82.5D	Screening	B11
HGB/83.3D	Detailed	B12

8.1 Testing Plan and Rationale

NAGRA (NIB 88-25) prepared a summary of the rationale and testing plan information to explain and document the decisions that were made as to how and what sections to test in the borehole. This reference provides the basis for this section of the report.

The geology, geophysics and drilling information was compiled and discussed in order to prepare the plan for the borehole testing program. The testing plan for the shallow 100 m boreholes involved two stages, screening and detailed tests. Between three and five screening tests were planned to completely cover the entire sequence from the base of the casing at about 20 m depth to total length. The detailed testing plan was then developed based on the results of the screening tests.

8.1.1 Geology

The geologic data reviewed prior to selecting the zones to be tested included core recovery, lithology, structural details such as shear zones and fracture types and spacing, and RQD. As for HVB, shear zones were not clearly definable from the core. The entire borehole was relatively homogeneous from both a lithologic and structural view point. Disturbed zones occurred at 47 m, 78 m and at 82 to 84 m. Low RQD zones occurred at 35 m and at 65 m. Several open fractures were logged from 55 to 57 m. No specific water conducting zones could be identified based solely on the core.

The RQD values indicated good packer seats over six zones at 24 to 27 m, 30 to 33 m, 40 to 63 m, and from 73 m to the total depth of 100.8 m.

8.1.2 Geophysical data

Geophysical information for the entire borehole included temperature, salinity, caliper, self-potential and gamma logs run by INTERGEO A.G., petro physical logs consisting of resistivity, density, neutron porosity, sonic, spectral gamma ray (kalium, uranium, thorium) and dipmeter run by BPB, and the SABIS televiewer run by WBK. The salinity log appeared to have been affected by incomplete circulation and mud particle settling in the lower 10 m of the borehole. The same effect may have accounted for the 0.5°C temperature decrease in the bottom of the borehole.

The results of the 8-arm caliper log were available after the start of the screening tests. Thus, caliper effects were not initially evaluated for the SP, density, neutron, and sonic logs. The microresistivity log showed a low at 78 m. The gamma log peaked indicating high clay content at 50 m, 78 m, and 82 m. Resistivity logs showed possible invasion of drilling fluid in some areas.

8.1.3 Drilling and other borehole information

No fluid losses were observed during the time the borehole was drilled. However, the fluid level declined about 25 m along the length of the borehole over about 24 hours during logging. This is equivalent to a fluid loss of about 150 to 200 litres. The fluid loss suggested that the borehole had intervals with higher transmissivities than those documented for HVB.

8.1.4 Screening test intervals

The similarity in borehole geology or geophysical responses accompanied by the observed fluid level decline in the borehole suggested the entire borehole should be screened to determine the zone(s) of potential fluid loss. Four screening zones were selected to determine which part(s) of the borehole had sufficient permeability to account for the fluid loss and possibly warrant sampling during the detailed testing. The screening plan decided upon just prior to the beginning of testing (Table 8.1) was for a straddle length of about 19 m with zones tested from about 73 to 92 m, 53 to 72 m, 33 to 52 m, and 13 to 32 m. Selection of a 19 m straddle length allowed testing the entire borehole with four packer seats.

Three screening tests were performed (Table 8.1 and Figure 8.1), starting at the bottom of the borehole. It was expected that the pressures and fluid levels in the borehole would be below grade as they had been in HVB. Starting testing at the bottom of the borehole reduced the variability in borehole history pressures for following tests.

Screening tests started on 19 June, 1987 and lasted about 2.5 days. The first three done (HVB/82.5D, HGB/62.5D, and HGB/42.5D) were similar to the original plan. The first and deepest screening test (HGB/82.5D) had a relatively high transmissivity. The P1 bottomhole response was relatively slow suggesting a lower transmissivity in the bottom seven metres of the borehole. The annulus fluid level did not drop during the deepest test suggesting that the HGB/82.5D zone had possibly been responsible for the noted fluid loss during geophysical logging.

The bottomhole pressures dropped during the next two screening tests (HGB/62.5D and HGB/42.5D) suggesting the lower part of the borehole was continuing to take water. At the same time, the annulus levels remained relatively stable. There was no observed fluid level or pressure change in the annulus during testing of the upper part of the exposed borehole from the base of the casing to the top of the HGB/42.5D interval at 33 m.

Therefore, the proposed fourth screening test in the upper part of the borehole was cancelled. Sampling the more permeable lower part of the borehole was considered more important than testing the relatively low permeability length expected in the upper part of the borehole.

The planned sequence of testing during the screening phase was modified to reflect the experience gained during the HVB testing. In general, it was to consist of the following basic procedures:

1. Inflation,
2. Compliance,
3. Shut-in pressure recovery towards static (Psr),
4. Pulse injection,
5. Slug-type test if adequate conductivity,
6. Constant rate/pressure test if time permitted,
7. Shut-in recovery.

<u>HGB/82.5D</u>

The water level in the tubing string dropped during compliance in the first screening interval. This drop confirmed the previous response in the borehole fluid level noted during the geophysical logging. Accordingly, a slug test was done after the initial pulse test with similar results to the compliance period. This plus the following shut-in recovery were treated as a drill stem-type test. Two additional pulse injection tests were done while the constant rate injection pump was connected. The injection was relatively successful and continued for about 80 minutes at an average rate of about one litre per minute.

<u>HGB/62.5D</u>

The testing sequence for the HGB/62.5D interval started out the same, but was modified because the response characteristics of the interval changed during testing. No fluid level drop was observed during compliance and the Psr response was relatively slow. However, the first pulse injection test responded completely to a pressure of 220 kPa, about one hundred kPa lower than the extrapolated shut-in response during the preceding Psr event. A second pulse injection test had a similar response. This suggested that part of the interval had been unplugged due to the overpressure applied during the pulse test. Three constant rate injection pumping events and associated recovery tests were then conducted to determine what pressures would develop with variable rate injections. In all three recovery events, the extrapolated end pressures were similar and about equal to those determined in the initial pulse injection tests. Injection rates averaged from about 75 to 350 ml/min, smaller than those achieved in the HGB/82.5D screening test interval.

HGB/42.5D

The final screening test started off with the same approach. No fluid level change occurred during compliance. However, the pressure rose slightly during the Psr event likely in response to continued packer inflation. This response suggested the interval would have relatively low transmissivity. This was confirmed with the following pulse injection event done using the downhole FAV. Because of the relatively low permeability, the interval testing was completed with a final pulse test using the HVT to increase the shut-in volume.

Summary

The screening tests results had illustrated that the lengths between about 53 and 93 m contained the zones that could account for the fluid losses observed earlier in the borehole. The deeper HGB/82.5D interval was considered to have the higher permeability based on the higher injection volumes at lower buildup pressures achieved in it compared to the HGB/62.5D interval.

8.1.5 Detailed intervals

The preliminary plan for detailed testing of HGB was made during the late hours of the third and final screening test. Discussion of the screening test results and the background geologic and geophysical data was the basis for the preliminary plan. The plan was again left relatively flexible in order to accommodate changes that would naturally occur as the results from the ongoing testing were discussed and their implications realized.

The preliminary plan developed consisted of the following program criteria:

1) Minimize the number of packer seats,

2) Close the P1 line-to-surface to remove the possibility of air in the line affecting the bottomhole response,

3) Concentrate on defining the most permeable zones in the borehole,

4) Conduct a gas test if the permeability is high enough,

5) Re-test a test interval to check for transient effects,

6) Test the upper currently untested part of the borehole,

7) Use a 6.6 m straddle since it conveniently covers the two screening test interval zones with 3 tests, fits good packer seats and will be adequate for testing the upper two intervals in the part of the borehole previously not tested.

The proposed plan based on the above criteria for detailed testing is given in Table 8.1. The plan consisted of testing every 6.6 m section from 73 to 92 m and 53 to 72 m section, retesting a zone, conducting a gas test in a permeable interval, and then finally, testing the untested part of the rock above the HGB/42.5D screening test interval, if time permitted. The actual testing is shown on Table 8.1 and Figure 8.1.

HGB/76.3D

The testing began with HGB/76.3D interval because it was believed from the geophysical logs to be the most permeable. There was a washout and a low uncorrected neutron log porosity value, possibly suggesting a fracture in the vicinity of 77 m. However, the testing was terminated after about nine hours because the interval was not permeable enough to account for the screening test response. The tubing fluid level did not drop during compliance, the pressure increased during Psr, and, the bottomhole pressure dropped relatively rapidly soon after inflation.

HGB/83.3D

At that point, further review of the geology and geophysics of the two other potential detailed test zones at this depth was made. However, there was no clear indication as to which of the two zones left to be tested was the more permeable one. The original plan was followed by moving the packers down to HGB/83.3D immediately underlying the HGB/76.3D interval. The tubing fluid level fell during compliance but the bottomhole pressure response was relatively fast. The falling liquid level confirmed that at least this zone had accounted for part of the earlier HGB/82.5D interval screening test response. The relatively rapid bottomhole response indicated part of the underlying rock could also have contributed to the HGB/82.5D screening test response. The interval was tested for 18 hours and groundwater sampling was initiated.

Only limited sampling success was obtained with the downhole pump because of both mechanical difficulties and the relatively low driving head at this depth. Swabbing was considered to be more efficient. It was initiated and continued for about three days. Borehole cleaning activities removed about 83 litres of water, smaller than expected. Sampling was terminated early due to this slow yield and the fact that the residual drilling fluid tracer concentration remained at about 70 percent and was levelling off. The final water sample taken had a volume of about 2 litres and contamination with drilling fluid of 67 percent.

The planned third detailed interval test in the 82.5D screening zone was cancelled to allow additional time to be spent in the other intervals above the HGB/82.5D screening interval. Annulus level measurements indicated water losses had occurred during testing of the HGB/76.3D and HGB/83.3D intervals. It was recognized at the time that there had been communication between the HGB/83.3D interval and the bottomhole zone during both the testing and sampling events. However, it was decided to use the P1 response from the HGB/83.3D interval in conjunction with the P1 response from the HGB/82.5D screening interval to differentiate relative contributions and hydraulic characteristics in the interval from about 88 to 93 m. It was also hoped that the fluid logging scheduled to occur at the end of the HGB testing would further delineate at what depths fluid was entering or flowing from the borehole.

HGB/68.7D and HGB/62.1D

Detailed testing continued by moving up sequentially in the borehole to complete testing in the HGB/62.5D screening interval. Neither HGB intervals 68.7D nor 62.1D responded rapidly enough to account for the HGB/62.5D screening test response. Annulus fluid levels continued to drop during these tests.

HGB/55.5D1

The fifth detailed test was the HGB/55.5D1 interval which is described in Section 6.2. It behaved in a similar manner as was described above for the HGB/62.5D screening test. The interval responded more quickly after the pulse event overpressure compared to the compliance and Psr events. The testing was completed successfully, and this relatively high transmissivity interval was considered as the most appropriate to both retest (HGB/55.5D2) and to test injecting with gas (HGB/55.5D GAS).

HGB/29.7D and HGB/23.7D

The sixth and seventh detailed tests were conducted in the upper part of the borehole. Both the HGB/29.7D and HGB/23.7D intervals illustrated relatively low transmissivities and they were terminated after pulse testing to allow for the follow-up hydraulic re-test and gas test in the HGB/55.5D interval.

HGB/55.5D2

The testing equipment was removed from the borehole and modified for the gas test. The hydraulic retest of the HGB/55.5D interval was started but the changes that had been made to the tool configuration for the gas test required that the former P1 line-to-surface was now hydraulically connected to the interval rather than to the bottomhole zone. This hydraulic connection to the interval affected the interval pressure response to such a degree that no quantitative comparison of the HGB/55.5D1 and HGB/55.5D2 tests was possible. However, in general, the responses were similar.

HGB/55.5D-GAS

The final detailed test was the HGB/55.5D GAS test. It was conducted to evaluate the hydraulic characteristics of gas movement through a water-saturated environment, a topic of increasing interest related to nuclear waste disposal environment behaviour. The gas test objectives were to estimate the pressure required, first to begin, and second to maintain as continuous, displacement of the water in the pore spaces by gas. This transient pressure testing also was to be used to estimate the intervals relative permeability to gas and attempt to differentiate near wellbore from interval characteristics. A detailed analysis of the gas test was conducted by technical experts and is presented in Appendix B6.

The gas testing was successful. A series of constant rate injections followed by shut-in recovery events were conducted over a period of about 24 hours. The gas test results are described in the Section 8.2.

Detailed test methods

The P1 line valve was closed at the surface and sometimes opened to see the response during the detailed testing. Changes in the fluid level in the P1 line reflected the bottomhole pressure response.

A standard approach was used for monitoring of inflation, compliance and the initial pulse events. Thereafter, the sequence of events that followed in each detailed interval was guided by the interval's transient pressure response. Intervals HGB/79.6D, HGB/62.1D, HGB/29.7D and HGB/23.1D were terminated after conducting only pulse testing due to their relatively slow response and low hydraulic conductivity. Intervals HGB/68.7D, HGB/62.1D and HGB/55.5D1 included final event pulse tests done with the surface HVT. Slug events commonly followed by shut-in pressure recovery periods were conducted in intervals HGB/83.3D, HGB/68.7D and HGB/55.5D1 because there was adequate transmissivity for flow under available under- or overpressure conditions. Constant rate injection tests were carried out successfully during the HGB/55.5D GAS testing.

8.2 Hydrogeologic Testing Results

Table 8.2 and Figures 8.2 through 8.5 illustrate the results of the analysis done on the nine double packer intervals tested in HGB.

As for HVB, preliminary analyses were done in the field and a Quick Look Report was prepared illustrating these results during and shortly after completion of testing in each interval. This was described in Section 4.2. The results described in this section are based on the interval report analysis results which incorporated the use of the borehole simulation model, GLIMPSE, described in Section 4.1.2. As such, the results should be considered as a first interpretation and are not considered representative or indicative of the conditions such as skin effect or fracture flow that may have been present at the time of testing. Rather, they illustrate values to be compared with a model assuming a homogeneous, isotropic medium with radial flow and wellbore storage conditions.

The bounding approach used in most of the analyses has resulted in ranges of values in many cases. The individual analyses found in NIB 88-03 should be referred to for a more complete understanding of the sensitivity of the bounding to variations in parameter values.

8.2.1 Borehole history

The pre-test activities that took place prior to any testing in the borehole lasted about nine days. The fluid level was at or near the top of the borehole during the drilling that lasted for about five days after setting the casing. The water level declined about 25 m along the borehole length during the 40 hours of geophysical testing. This means that the intervals tested were subject to inflow conditions and higher pressures than in-situ conditions. The length of time that these generally higher pressures lasted varied from about three and one-half days in the case of the first screening test, HGB/82.5D, to about 19 days in the case of the final detailed test, HGB/23.1D.

The extent of the overpressure can be estimated if it is assumed that the hydraulic head values determined in the HGB/55.5D1 and HGB/83.3D intervals are representative of the rest of the borehole. Both values suggest heads on the order of about 22 to 32 m below the reference point. Thus, the overpressures, ignoring temporarily higher pressures at the bit face, will have been about 220 to 320 kPa.

Figure 8.1 illustrates each intervals testing pressure dependency.

8.2.2 Formation static pressure and hydraulic head

Pressures believed to be representative of the intervals tested were determined for the HGB/55.5D1 and HGB/83.3D detailed tests. In addition, pressures were determined for the first two screening tests (HGB/82.5D and HGB/62.5D) which included these intervals. Higher confidence should be given to the pressures of the detailed test zones and their associated hydraulic heads since the interval associated with the contributing zone is thinner.

The pressure data as shown on Figure 8.2 and given in Table 8.2 suggest a gradient of between about 5 kPa/m depth, below normal hydrostatic conditions. This is based on estimated values of static pressure for the HGB/55.5D1 and HGB/83.3D intervals.

Head values (Table 8.3) calculated for the same two intervals were about 467 and 462 m(asl), respectively, suggesting a decreasing hydraulic head with depth. A difference in 50 m head occurs between these two zones separated vertically by 21 m.

Table 8.4 list the extrapolated end pressure values for the bottomhole zones monitored during the HGV interval testing. Hydraulics head elevation values calculated from the pressure response ranged from 451 m to 484 m (asl).

8.2.3 Transmissivity and hydraulic conductivity

Figure 8.3 is a profile of transmissivity versus HGB borehole true vertical depth. A relatively wide range of transmissivities were determined for the nine intervals tested. Two zones in the vicinity of HGB/55.5D and HGB/83.3D have transmissivities greater than 1e-08 m2/s. The rest are less than 1e-09 m2/s. Hydraulic conductivity values, assuming contribution is equally distributed throughout the interval tested, were less than 1e-10 m/s except for the narrow widths of contributing zones for HGB intervals 55.5D1 and 83.3D which had values of about 1e-09 to 1e-08 m/s.

The results from the two screening tests are consistent with the follow-up detailed tests in similar intervals. The HGB/82.5D screening test with a transmissivity of about 2e-08 m2/s to 2e-07 m2/s had it's contribution zone in the HGB/83.3D detailed test interval with an estimated transmissivity in the range from 7e-08 m2/s to 3e-08 m2/s. Part of the HGB/82.5D contribution was likely also to come from the immediately underlying rock in the lengths from about 87 to 93 m. The HGB 76.3D detailed test had a value of less than 1e-11 m2/s.

The HGB/62.5D screening test with a value of about 2e-08 m2/s to 2e-07 m2/s compares to the 3e-08 m2/s to 7e-08 m2/s values for the well documented contribution zone in the HGB/55.5D interval. The two other detailed tests in this interval had values of less than 7e-10 m2/s. Clearly, the dominant contribution was from the HGB/55.5D interval.

There is no trend evident from these results relative to depth in the borehole.

Finally, some comments are in order regarding the results of the gas test. First, the gas permeability results were comparable to the water medium transmissivity values from the initial hydraulic testing in the zone (HGB/55.5D1). Second, a low skin value was determined for the period of testing. However, the value of skin factor determined may not be representative of the initial interval conditions at the start of either the HGB/62.5D or HGB/55.5D1 tests. In both these previous testing situations, it appears that a skin factor may have been overcome due to the pulse injection event overpressures. Third, the steady state conditions that occurred during each gas injection period showed that there is a relatively low threshold pressure required for gas to displace water from the formation. The end of wellbore storage and the onset of inflow into the formation occurred at about 5.4 bar.

8.2.4 Specific storage

Figure 8.4 illustrates the ranges of specific storage determined using the bounding approach. In general and as noted for HVB in Section 7, there is much less sensitivity in this parameter value than in the pressure or transmissivity/hydraulic conductivity values for bounding theoretical response. Sensitivity analyses done during the field report bounding analysis are reported. At this time, it is not possible to comment on which value within the range used may be representative. The values used in the bounding ranged from about 1e-8/m to 2e-4/m. In general, a three order of magnitude range was used for each interval. No more certainty could be expected with the bounding approach used.

8.2.5 Temperature

Figure 8.5 shows the temperature data measured in HGB testing indicating a range from about 16°C to about 17°C. No depth trend is evident. As for HVB, temperature profiles for the borehole should more realistically be based on the results of the geophysical logging.

9. RESULTS OF SA

The purpose of this section is to summarize the testing that was done in the third and last of the boreholes drilled and tested, the 348.5 m vertical borehole referred to in the NAGRA planning documents as SA. The rationale for and development of the borehole testing is presented followed by a discussion of the results from the testing.

Drilling started on 07 July, 1987 and was completed 30 days later at a total depth of 348.5 m below the reference point. Surface casing was set to a depth of 22.1 m. The entire borehole was cored and logging of the core was done on-site as drilling progressed. In this borehole, drilling was not completed to total depth prior to the start of testing. The details of the borehole activities are given in Table 9.1. Two single packer tests, an open borehole injection test and two rounds of borehole geophysics were done interrupting the drilling four times prior to reaching total depth. After reaching total depth, geophysical logging was done followed by the first two double packer tests. Geophysics and borehole stability improvement (without drilling fluid additives) were again undertaken followed by the last four double packer tests.

A total of seven different intervals were tested, two with single packers and five with double packers. One of the double packer intervals was tested twice. The constant packer pressure system used for the HVB and HGB testing was continued for the SA testing. Due to borehole instability in the 236-262 m section, the downhole testing equipment was moved-in through drill pipe without bit and core barrel. No problems occurred using this procedure. Summaries of the eight SA tests are given in Appendix C as follows:

Test Interval	Packer Configuration	Appendix Number
SA/100.2S	Single	C1
SA/137.0D	Double	C2
SA/157.0D	Double	C3
SA/160.6S	Single	C4
SA/196.5D1	Double	C5

Test Interval	Packer Configuration	Appendix Number
SA/196.5D2	Double	C6
SA/298.0D	Double	C7
SA/311.0D	Double	C8

9.1 Testing Plan and Rationale

NAGRA (NIB 88-25) prepared a summary of the rationale and testing plan information to explain and document the decisions that were made as to how and what sections to test in the borehole. This reference provides the basis for this section of the report.

The primary purpose of the SA borehole was to determine the geologic nature of the rocks underlying the Valanginian marls that had been encountered and tested in the first two boreholes. The initial planning for the borehole (NTB 87-04) involved drilling, geophysical logging and hydraulic testing to be done at three geologically defined depths. The first break was to be at about 100 m with one or two tests to be done to confirm the findings of the HVB and HGB boreholes. The second break was to perform one or two tests in possibly more permeable horizons at about 250 m. The borehole was then to be drilled to total depth intersecting either the Valanginian limestone or the Tertiary shales underneath. At this point, about 10 hydraulic tests were to be done in a manner similar to that in the HVB and HGB boreholes.

The plan was adapted to the conditions encountered during drilling. Fluid loss zones were encountered and tested. Borehole stability problems prevented testing some zones in the range of 236 to 262 m.

9.1.1 Geology

Both lithologic and structural geology information was continually available. This, RQD and core recovery data were used in conjunction with borehole drilling information to reach a decision to interrupt drilling for logging and testing. After completion of drilling, these data were also used to plan the final double packer tests.

9.1.2 Geophysics

Geophysical logging was done on separate occasions (Table 9.1) over the duration of activities at SA. The extent of logging was a function of both the time available for logging and the condition of the borehole. Logs similar to those run in HVB and HGB were run in SA, although there were only two occasions when the complete set of logs were run.

Specific information that assisted test planning was obtained after drilling to total depth. In general, good packer seats were determined from both the caliper and the SABIS logs. Potential fluid invasion zones were seen from the resistivity logs.

A fourth series of logs was run after completion of testing to get further information on the zones responsible for fluid loss in the borehole.

9.1.3 Drilling and other borehole information

Testing during drilling is more costly than testing after drilling is completed. The rationale and justification for testing during the first two depth stages had to be declined. No fluid losses were observed during drilling of HVB or HGB. However, the HGB fluid level declined about 25 m during logging. Monitoring of fluid level changes in the SA borehole between core runs was done up to three times per day as drilling continued below the surface casing. This activity, referred to as a 'flow check', was begun because of the fluid losses that had been documented in HGB during logging.

Flow checks during drilling became the focal point for the rationale for interrupting drilling to conduct both geophysical logging and testing. Table 9.2 contains a summary of the relevant flow check and related data used for implementing the testing in SA.

9.1.4 Intervals tested

The following descriptions are for the testing during drilling (Section 9.1.4.1) and after reaching the total depth (Section 9.1.4.2). They demonstrate how the incoming geologic and borehole data was used to modify the generally defined testing program both 'immediately' in the case of the single packer tests and, some of the double packer tests, and after compiling and considering the data base in the case of the last double packer tests.

9.1.4.1 Intervals tested during drilling

Two single packer tests and an open borehole injection test were conducted prior to completing drilling at a total depth of 348.5 m. Attempts were made to test at a total depth of 300.2 m but they were not successful due to hole instability problems between about 236 and 262 m.

SA/100.2S

Fluid losses during flow checks began at a depth of about 30 m and had reached a rate of about 0.1 litres/min by the time drilling had reached a depth of 76 m on 13 July, 1987. These results justified plans to lower the fluid level in the borehole and conduct fluid logging to pinpoint the loss zone. Drilling continued, however, while the logging companies were mobilizing to the site. Prior to their arrival, a 600 litre fluid loss occurred during drilling at a depth of about 101 m.

Subsequent flow checks to the drilled depth of 103.1 m indicated losses between 2 and 3 litres/min.

Drilling was stopped, the borehole fluid was circulated, and the fluid level in the borehole was lowered by forcing air through down the annulus and up through the installed tubing to the surface. The results of the following geophysical logging (salinity temperature) did not positively indicate the depth of the fluid loss zone. A single packer configuration was decided upon with the packer to be set above the permeable zone at a depth of between 96 and 99 m.

Testing began at 15:00 on 16 July,1987, about 40 hours after stopping drilling. The objective at the outset of testing was first, to estimate hydraulic characteristics, and second, to take a fluid sample. Testing began with the standard inflation, compliance and Psr events. The fluid level in the tubing fell during compliance, and the pressure continued to decline during the four hour Psr event. The fluid level in the tubing was blown out to allow a slug withdrawal event to be done rather than inject additional fluid into the interval. The fluid level rose about 24 m up into the tubing during the slug flow although the response time was slower and the calculated field transmissivity of about $1e^{-6}$ m^2/s was less than had been anticipated based on the flow check and fluid losses during drilling.

Groundwater sampling began after testing was complete. Attempts at airlifting the fluid with the FAV open did not work. Interval cleaning and sampling was done over the following 61 hours by periodically blowing out the fluid from the tubing with the FAV closed, and then opening the valve for recovery to occur. The flow rate decreased from about 0.8 litres/min to 0.04 litres/min during this time. The final 6 hours of sampling was spent obtaining a pressurized sample. Sampling was terminated after about 430 litres of fluid had been obtained and the tracer concentration had been stabilized at a level of about 45 percent. The final water sample taken on 19 July, 1987 had a volume of about 65 litres. The remaining contamination by drilling fluid was about 45 to 50 percent.

Sampling and testing equipment were removed from the borehole and drilling resumed on 19 July, 1987 at about 23:00 hr.

SA/160.6S

Drilling continued over the next three days to a depth of about 157.5 m. Ongoing flow checks indicated decreasing fluid losses suggesting the zone tested previously and any other zones in the open borehole were being plugged. Flow checks indicated losses had decreased to about 0.1 litres/min compared to the rate of 2 litres/min observed prior to the SA/100.2S test.

A fluid loss during drilling occurred during the core run between 157.5 m and 160.2 m on 22 July, 1987. The subsequent flow check indicated a loss rate of about 15 litres/min, the largest loss to date for the Oberbauen program. Coring continued for about the next 6 m and was stopped at a depth of about 166 m.

Flow checks were conducted over the next five hours indicating first, a decrease in rate to about 5 litres/min with the fluid level dropping to 39 m below the top of the drill pipe, and second, the fluid level in the open borehole continuing to drop after the drill rods had been removed from the borehole. Prior to lowering the test equipment in the borehole, the open borehole fluid level had declined to over 96 m below the tunnel floor and fluid loss rates were about 0.7 litres/min.

Experience from the SA/100.2S interval and continued drilling suggested that zone plugging was occurring with elapsed time. Therefore, no logging was done prior to hydraulic testing in order that the testing equipment could be on depth as soon as possible.

The fact that the fluid level had fallen about 100 m below the tunnel floor level was a surprise. Testing was targetted first, at determining hydraulic parameters of the interval, and second, at sampling any fluid. The single packer assembly was lowered keeping the packer above the 157 m depth. This isolated the bottom nine meter test zone, where the losses had occurred, from the rest of the borehole.

Testing began with the standard inflation, compliance and Psr events. The tubing fluid level dropped during compliance and the pressure continued to drop during Psr to less than 300 kPa. This pressure corresponded to a head elevation of about 357 m (asl). This suggested that the interval would not be suitable for obtaining a water sample. The low pressure and head in the zone created site conditions that had not been anticipated. It had not been expected that a zone with a relatively high hydraulic conductivity would occur with a hydraulic head of about 140 m below the drilling gallery floor.

After completion of the Psr, attempts were made to lower the fluid level in the tubing using one of the on-site pumps. An in-progress slug injection test was impacted accidentally by lowering a pump into the fluid before the FAV had been closed. The pump was used to withdraw fluid from the tubing after closing the FAV. The following slug withdrawal test started with about 10 m of fluid in the tubing string above the interval transducer and finished after an inflow of about 7 m of fluid.

The sampling activities were cancelled after observing the low rate of fluid recovery during the slug withdrawal test. Additional testing in the zone consisted of a second slug injection test and shut-in recovery and a final constant pressure injection period. The constant pressure flow event was done to evaluate if a longer term injection test could be done to evaluate the zone boundaries. Water was injected at a pressure of about 1600 kPa with a rate of about 1 to 1.5 litres/min, a rate too low to warrant additional boundary-type testing. Testing was therefore terminated and the testing equipment was removed from the borehole.

Open-borehole injection test

Drilling resumed at 10:00 on 24 July, 1987 and was again stopped about 8 m deeper at a depth of 174.2 m. NAGRA decided to further test the zone at the bottom of the borehole by conducting another injection test with higher flow rates and injection pressures. Concern had been expressed about limitations of the tubing and packer testing equipment to allow unimpeded flow at rates in excess of 1 litre/min. This, plus the time required to assemble and lower the testing equipment, were the rationale for proceeding without the use of packers to isolate the test section of interest. The rationale was further that the flow would go into the zone most recently tested since it had the lowest head, a relatively high conductivity, and had not been exposed to plugging conditions as long as the zone at 100 m depth.

The testing performed consisted of two injection periods. Traced water was injected with the main drill rig pump. Monitoring of the recovery was done by measuring the pressure falloff on a pressure gauge at surface. This continued until the fluid level went below the gallery floor. Thereafter, the fluid level drop in the borehole was measured with a water level meter. The first injection period lasted about 10 hours during which time about 4.3 m^3 were injected at overpressures of between 14 and 16 bar. The first shut-in recovery lasted about 100 minutes during which time the pressure at the surface pressure gauge dropped to zero. The falloff of the water level beneath tunnel floor was, however, not monitored. Instead, water injection was resumed.

The second injection period lasted about 12 hours during which time about 3.2 m^3 were injected at overpressures of between 10 and 14 bar. The subsequent final recovery period continued for 18 hours during which time the fluid level dropped to about 90 m below the top of the drill pipe that is to about 405 m(asl). Testing was terminated and drilling was resumed on 26 July, 1987.

The testing indicated that injection could be done into the borehole albeit at lower rates than had been predicted. Interpretation of the data by NAGRA indicated that the testing implied a low-pressure reservoir with considerable extent. No boundary in the immediate vicinity of the well had been recognized based on the available data.

Drilling to 300.2 m

It was decided to continue drilling to reach the Valanginian limestone contact or until another fluid loss of at least 5 litres/min occurred. Drilling losses continued to be monitored and flow checks were regularly done. One fluid loss of about 5 litres/min occurred during drilling at between 263 and 266 m on 30 July, 1987. The follow-up flow check confirmed a rate of about 1 litre/min. Drilling continued to 288 m at which depth the contact with the Valanginian limestone was encountered. Drilling continued to 300.2 m and confirmed the presence of the underlying formation, macroscopically similar to the Valanginian marl.

Attempts to run geophysical logs at this depth were terminated because of hole instability between about 236 and 262 m. Bridging prevented logging this section of the borehole. Testing plans were cancelled and drilling resumed. Drilling was planned to the Tertiary contact or a maximum additional depth of 100 m.

9.1.4.2 Intervals tested after drilling

Five intervals were tested after completion of drilling, one of them twice. The borehole drilling was completed at a total depth of 348.5 m in marlstone of Valanginian or Tertiary age. Drilling fluid was changed and full recirculation occurred. Again, difficulties occurred accessing the 236 to 262 m depth area. The drill pipe was placed through the zone and logging was done in the bottom of 80 m of the borehole. Testing was therefore, to be done, first, in the bottom part of the hole and second, higher in the borehole.

Preliminary plans for the final testing of SA were made during the geophysical logging and borehole stabilization activities on 6 and 7 August, 1987. The primary objective of the first part of the testing was to obtain a representative pressure and hydraulic head. Emphasis for the second part of the testing above the problem zone was to both confirm the anomalously low pressure and head, and attempt to estimate the size of the zone near the SA/160.6S interval. The plan had several additional constraints and objectives reflecting the anomalous and surprising pressure/head results determined to date.

The core and the geophysical logs of the bottom part of the hole were reviewed. Packer seats were picked and priority assigned to the testing. None of the core or log data, except for a salinity spike at 297 m suggested any zone of potential fluid loss or contribution. Therefore, plans were made to proceed in a manner similar to that used for evaluating the permeable screening test intervals in HGB, namely, test the section until a permeable zone is found.

Table 9.3 contains the proposed and final packer testing intervals for the bottom part of the borehole. To test this part, the testing tool had to be moved in and out through drill pipe.

The testing procedures to be followed, given the emphasis for a good pressure and hydraulic head measurement, were basically the same as had been used previously in the HVB and HGB detailed testing program. Compliance and Psr would be followed by a pulse injection test and a slug injection or withdrawal event, and finally, the following shut-in recovery would last long enough to obtain a good head measurement.

At that point, further review of the geology and geophysics, borehole condition and results of the hydrogeologic testing to date occurred together with senior NAGRA management. The program was modified slightly with emphasis still placed on documenting a head in the lower part of the Valanginian limestone. Assembly of the testing equipment with a 15 m double packer straddle length began on 07 August, 1987. Modifications were made to the tool to allow it to fit through the drill rods. The tool was lowered into the borehole beginning at 22:00 on 07 August, 1987.

Concern had been expressed about first, lowering the tool through the drill rods because of the small clearances, and second, being able to retrieve the tool back into the drill rods. There were no difficulties associated with either operation. This indicated that testing through the drill rods after removal of the bit and core barrel was a viable testing technique.

SA/298.0D

There was no clear indication as to which of the three proposed bottomhole test zones was more permeable, and therefore, the one to be tested to obtain a good head measurement. The shallowest zone from 290 to 308 m was chosen as the interval to test first, mostly because of the salinity spike at 297 m.

Shortly into the Psr event, it was clear that this interval did not have adequate permeability to obtain a hydraulic head. The pressure did not change during Psr, and the annulus and interval pressures were similar. A check for communication was done during the first pulse injection test. None was observed and the interval response suggested that the zone was tight.

Testing continued with a second pulse test and final slug withdrawal and recovery period. Even with the relatively slow responses in the interval, the testing continued for about 27 hours mostly to monitor the more permeable bottomhole pressures. The final bottomhole pressures indicated hydraulic head values near that of the Lake Uri level.

SA/311.0D

This test is described in detail in Section 6.3. The equipment was moved down to below the 298.0D interval, except for a 2 m overlap required because of good packer seats. The tubing fluid level fell during compliance indicating that the interval was taking water. The bottomhole pressure response was relatively slow, even after an initial increase due to packer squeeze. These two conditions suggested that this zone had accounted for most of the earlier SA/298.0D bottomhole pressure response. Flow into the tubing string occurred during the four hour slug withdrawal event. The extrapolated shut-in end pressure from the 13 hour recovery test was similar to hydraulic head values determined for the bottomhole response during 298.0D. The interval was tested for a total time of about 25 hours.

The objective of obtaining a hydraulic head measurement in the bottom part of the borehole had been met. Testing in the underlying Tertiary rock was cancelled in favour of spending more time in the upper part of SA above 236 m. The SA/311.0D bottomhole pressure response had suggested low permeability in the lowest part of the borehole.

Additional planning

The anomalously low pressure documented in the SA/160.6S test continued to be discussed related to planning the final testing, in the SA borehole. Planning strategy decided upon on 12 August,1987, just prior to the final testing included the following:

1) A good pressure/hydraulic head should be obtained in the depths between 160 and 236 m. Two test intervals should be planned for this depth range recognizing, at the same time, that the rock may be too tight to determine a representative pressure in just two days.

2) An injection test should be done in the zone near the SA/160.6S interval to see if the pressure can be increased. The fluid level in HVB should be monitored during this testing.

3) Additional testing and a well documented pressure/hydraulic head in the depths between 100 and 160 m would be useful, first to see its relationship to the Lake Uri level and, second, to define the size of the low pressure zone.

4) Testing sequence and maximum time lengths would be first, between 160 and 236 m for up to 3 days, second, between 100 and 160 m for one day, and last, the injection test in the SA/160.6S vicinity for up to 5 days.

5) Injection testing in the vicinity of 160 m should be done in a series of steps after monitoring the shut-in in-situ static conditions.

Later that day, the packer seats were picked and a 19 m straddle length was selected and confirmed as feasible. A surface test of the downhole FAV at flow rates up to 50 litres/min demonstrated there was no pressure drop through the FAV at these rates. The FAV was kept in the testing string for the final three interval tests.

<u>SA/196.5D1</u>

The testing in this interval began on 13 August, 1987. The fluid level dropped about 0.4 m during compliance. However, complete hydraulic testing could not be done because the FAV failed to open at the end of the Psr event. The testing was continued for about 62 hours to monitor the shut-in interval pressure. Then, the tool was removed from the hole to repair the FAV.

The interval was subsequently retested (SA/196.5D2 below).

<u>SA/137.5D</u>

A zone between the SA/160.2S and SA/100.6S intervals was tested beginning on 16 August, 1987. The testing objective was hydraulic head. The tool went in with the tubing dry in order that a slug withdrawal test could be done with the maximum possible drawdown. No open-tubing compliance period could be done. Accordingly, the packer squeeze that induced a pressure peak in the interval during inflation continued for some time. The zone was not permeable enough to determine a representative head for the interval in the allotted testing time. Testing was terminated after about 22 hours and the equipment moved down to retest the SA/196.5 interval.

SA/196.5D2

The retesting of this zone started on 17 August, 1987 and lasted for 14 hours. The purpose of the retesting was to conduct enough testing to evaluate the interval hydraulic parameters, and to further document the zone pressure. The testing results did not clearly establish a representative pressure for the interval. Trends for the retesting, were however, similar to the original testing. Testing terminated in the zone and the packers were moved up to the last test interval.

SA/157.0D

The final testing in SA and in the OBS-1 testing program began on 18 August, 1987 and lasted for about 6 days. The planned activities described above for the injection testing were followed. As for the SA/137.0D interval, the fluid level in the tubing string was lowered with only a little water in it and with the FAV closed. This allowed a slug withdrawal test to be performed with as high a differential as possible at the end of the Psr event.

Packer squeeze occurred during inflation and resulted in a large 1700 kPa overpressure. The Psr lasted about 10 hours at which time the pressure declined to about 800 kPa and was still decreasing, indicating the interval was relatively tight. The initial slug withdrawal event had an anomalously rapid initial rise followed by a small but regular flow into the tubing string. The subsequent buildup and the second slug withdrawal period responded in a manner similar to the second part of the initial slug withdrawal event.

For the subsequent injection tests, the main pump of the drill rig was connected to the test tubing. Testing consisted of three injection periods and related downhole shut-in recoveries. Injection rates were different in the three steps. Rates of 2 to 3 litres/min, 10 to 16 litres/min, and about

6.5 litres/min occurred at overpressures of about 45, 62 and 65 bar, respectively. A "breakthrough" took place during the 2nd stage with 62 bars P, increasing the rate to 16 L/min. Fluid bypass through the rock from the interval to the bottomhole zone was suspected during the first injection event. The breakthrough was confirmed during the second injection stage and continued in the third. Figure 3.13 illustrates that response.

The fact that there was fluid bypassing the interval packer boundaries made attempts to determine a reservoir limit or volume difficult. Extrapolated pressure values increased sequentially for the three shut-in recovery periods, but the fact that the bottomhole pressure also increased makes interpretation of this particular interval data difficult.

Perhaps the most surprising part of the testing was the difference in the hydraulic response of the zone at this point compared to the testing earlier in the single packer test SA/160.6S. The influence of borehole history on the zone can only partly account for higher pressures at the beginning of the interval testing in SA/157.0D. Some plugging seems to have occurred between the two tests. The slow Psr response strongly suggests that the interval characteristics changed since initially tested as SA/160.6S.

Testing was terminated after about 180 hours and the equipment was removed from the borehole thereby finishing the hydraulic testing program OBS-1.

<u>Test methods</u>

The P1 line-to-surface was plugged downhole prior to all the SA testing. Changes in the fluid level in the P1 line no longer influenced the bottomhole pressure response.

A standard approach was used for monitoring of inflation, compliance and the initial pulse events. Thereafter, the sequence of events that was followed in each detailed interval was guided by the interval's transient pressure response. All intervals had slug-type testing except the first attempt at SA/196.5D1 when the FAV failed to open. Constant pressure injections were done in the SA/160.6S and SA/157.0D intervals where the anomalously low pressures were encountered.

9.2 Hydrogeologic Testing Results

Table 9.4 and Figures 9.2 through 9.5 illustrate the results of the analysis done during the two single packer and six double packer intervals tested in SA.

As for HVB and HGB, preliminary analyses were done in the field and a Quick Look Report was prepared illustrating these results during and shortly after completion of testing in each interval. This was described in Section 4.2. The results described in this section are based on the field report analysis results which incorporated the use of the borehole simulation model, GLIMPSE, described in Section 4.1.2. As such, the results should be considered to be a first interpretation and are not considered representative or indicative of the conditions such as skin effect or fracture flow or gas effects that may have been present at the time of testing. Rather, they illustrate values to be compared with a model assuming a homogeneous, isotropic medium with radial flow and wellbore storage conditions.

The bounding approach taken to the analysis has resulted in ranges of hydraulic parameter values in many cases. In addition, the individual analyses of each interval presented in NIB 88-04 should be referred to for a more complete understanding of the sensitivity of the bounding to variations in parameter values.

9.2.1 Borehole history

The pre-test activities that took place prior to testing in the borehole lasted from 23 to 45 hours in the case of the single packer tests during drilling to about 28 days for the final testing that occurred after completion of the drilling and other work that followed testing of the SA/160.6S interval. The fluid level was at or near the top of the borehole during most of the drilling. It declined during the geophysical logging prior to the testing of 100.2S and prior to the testing of the SA/160.6S interval. Levels also declined during the time that the final testing was being conducted. Even with decline of the fluid levels, the intervals tested were subject to variable inflow conditions and generally higher pressures than in-situ conditions. The length of time that these generally higher pressures lasted also varied. Borehole history time prior to testing the final six double packer intervals was from about 5.5 days for the SA/311.0D zone to about 28 days for the final testing of the SA/157.0D zone.

The extent of the overpressure can be estimated if it is assumed that the hydraulic head values determined in the SA/100.2S, SA/160.6S and SA/311.1D zones are representative. The 100 and 300 m depths had head values of about 60 m below the gallery floor. However, at least the 160 to 200 m depths had head values about 130 to 140 m below the gallery floor. Thus, the drilling overpressures, ignoring temporary pressures at the bit face, will have been between about 600 and 1400 kPa.

Figure 9.1 illustrates each interval's testing pressure dependency.

9.2.2 Formation static pressure and hydraulic head

Pressures believed to be representative of the intervals tested were determined during testing for the SA/100.2S, SA/160.6S, and SA/311.0D intervals. Subsequent analyses suggested that the values for the SA/196.5D intervals fit the trend as well. The other intervals tested were too tight to assess their pressure.

The pressure results shown on Figure 9.2 and given in Tables 9.4 and 9.5 and illustrate a negative pressure gradient of about -3 kPa/m from SA/100.2S to SA/160.6S with a reversal of the trend in the lower part of the borehole to a positive gradient of about 17 kPa/m from SA/196.5D to SA/311.0D. This is based on values of static pressure of 515, 340, 620, and 2550 kPa for the four above-referenced zones, respectively.

Head value elevations calculated were 431 and 435 m(asl) for the upper and lower SA/100.2S and SA/311.0D intervals. Heads were about 70 to 90 m lower at 340 to 360 m(asl) for the SA/160.6S and SA/195.5D intervals.

Table 9.6 gives presures and head values determined for the bottomhole zones.

The low pressure documented in the middle of the borehole caused considerable concern during testing, first about the equipment reliability. Underpressures such as these have rarely been experienced in this type of testing program, and not to date in any of the Northern Switzerland environment. After the equipment was checked and determined to be working effectively, then discussion, particularly during the SA/160.6S test, centered around why the pressures were so low. No proof exists at this time why the pressures were so low, but there is no doubt that the conditions were real.

It appears feasible that the drilling intersected a former gas-saturated reservoir. With time, the gas and pressure in the reservoir could have emptied through a fault connected with the Seelisburg tunnel or an erosional surface that intersected the atmosphere. The reservoir may have been one of the gas sources encountered some 15 years ago during the excavations and drilling of the Seelisburg tunnel. The available pore spaces of the reservoir normally would fill with water. In this instance, this has not occurred and the continual low pressure could be accounted for by the inability of water to move quickly through the relatively low permeability marl-type host rock surrounding the reservoir.

If this situation occurred, it may be that the zones intersected were initially unsaturated. This could account for the higher fluid losses measured during the drilling compared to the available recovery when testing and sampling was done later in the interval testing. It could also account for the apparent higher pressure and lower permeability in the vicinity of the SA/160.6S interval when the SA/157.0D injection testing was done later.

9.2.3 Transmissivity and hydraulic conductivity

Figure 9.3 shows the transmissivity versus depth for the intervals tested. Transmissivity ranged from about 5e-11 m2/s for the SA/298.0D interval to about 1e-06 m2/s for the SA/100.2S interval. No trend with depth is evident as expected with fractured and structurally deformed alpine environments. Hydraulic conductivity values, assuming contribution is equally distributed throughout the interval tested, were from 1e-12 m/s to 1e-7 m/s.

The results from the two tests in the 160 m range were consistent even when considering the pressure bypass that took place during the SA/157.0D injection testing. The bypass that took place illustrated that there was likely connection to the undisturbed rock and reservoir below the bottom of the borehole during the testing of the SA/160.6S interval. Thus, that test was only partially penetrating the existing reservoir.

9.2.4 Specific storage

Figure 9.4 illustrates the ranges of specific storage determined using the bounding approach. In general, there is much less sensitivity in this parameter value than in the pressure or transmissivity/ hydraulic conductivity values. Sensitivity analyses done during the field report bounding analysis are reported in detail in IR's (NIB 88-04). At this time, it is not possible to comment on which value within the ranged used may be representative. The values used in the bounding ranged from about 5e-9/m to 2e-4/m. In general, a three order of magnitude range was used to attempt to bound the response for each interval. No more certainty could be expected with the bounding approach used. In general, the higher the specific storage used, the lower the hydraulic conductivity required to bound the data. The low values may suggest that a fracture flow model would be more appropriate than the porous media approach.

9.2.5 Temperature

Figure 9.5 shows the temperature data for SA indicating a range from about 18.3°C to 23.6°C. The linear gradient with an average increase of about 2.7°C/100 m is evident . This compares favourable to the gradient from the results of the geophysical logging.

10. References

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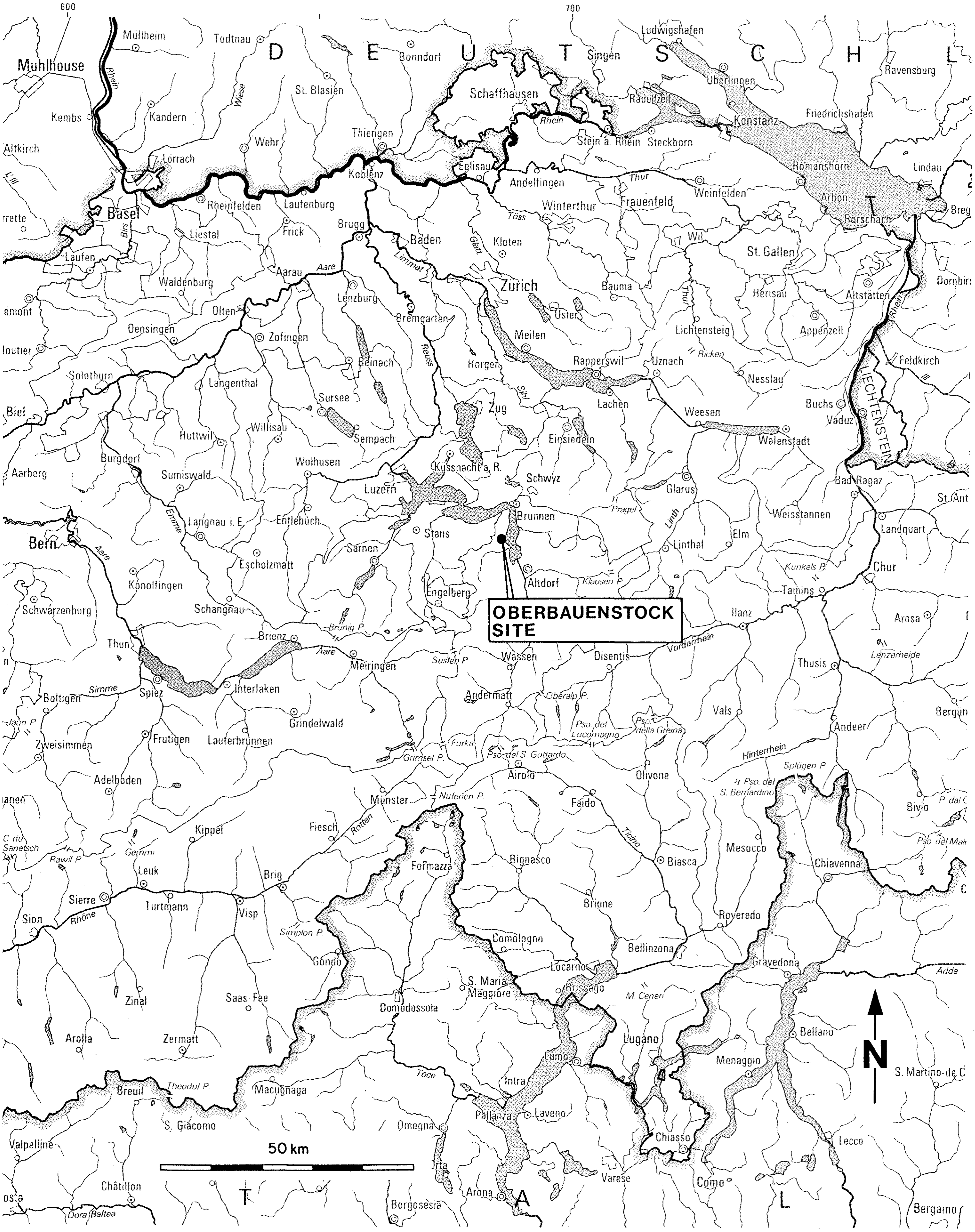
TEXT FIGURES



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SITE LOCATION REFERENCE MAP		
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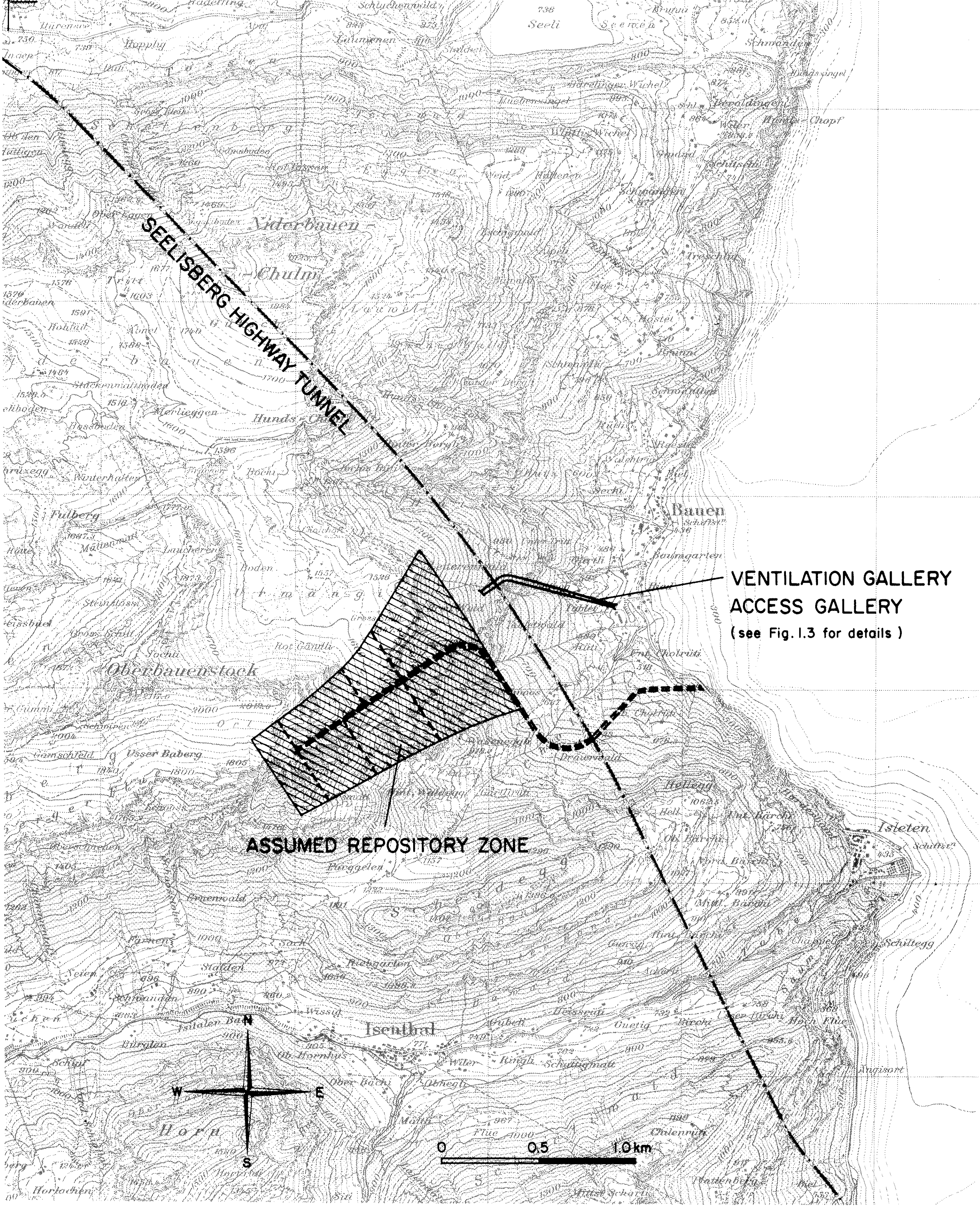

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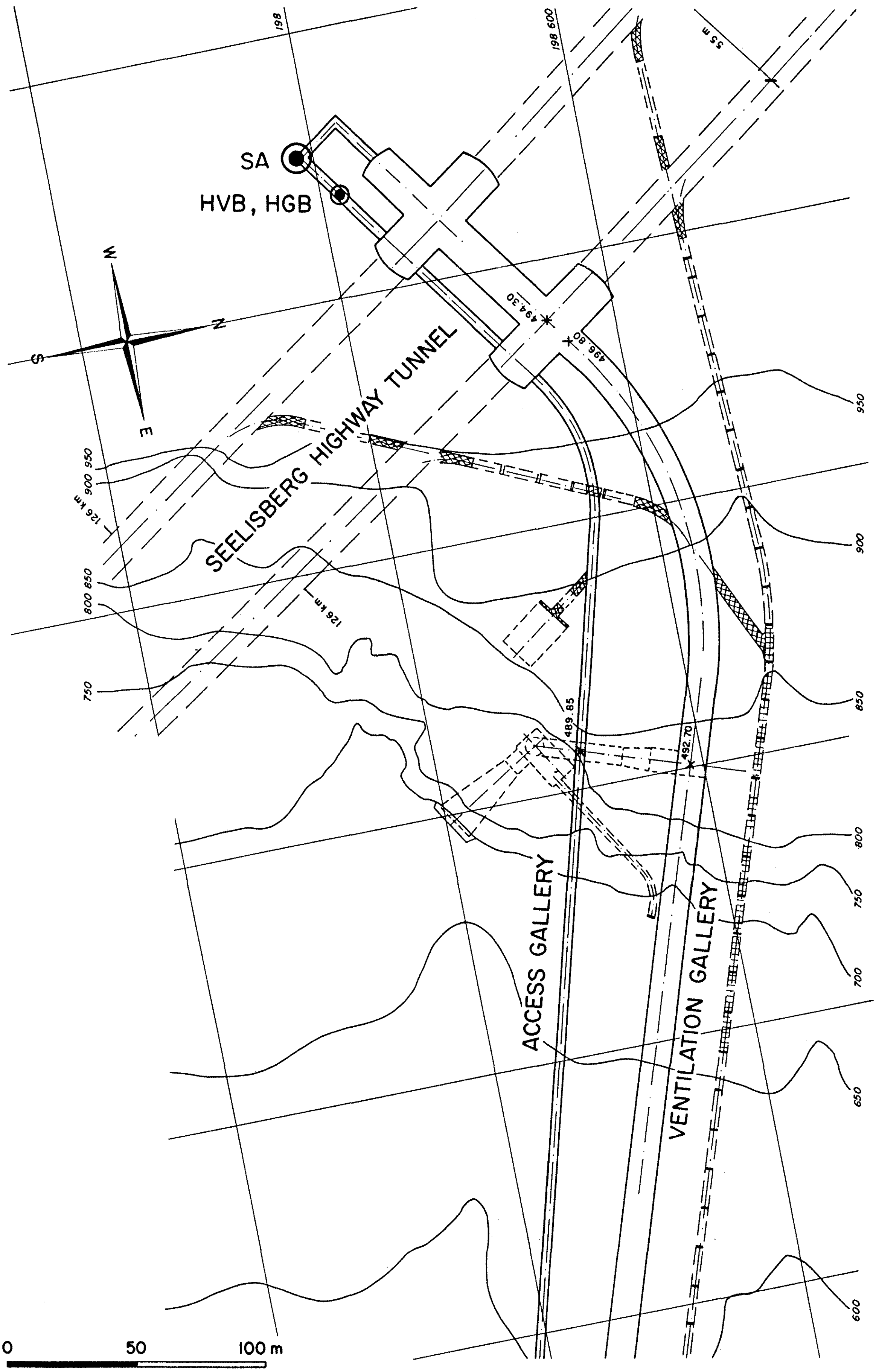

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LOCATION OF DRILLINGS HVB, HGB AND SA	
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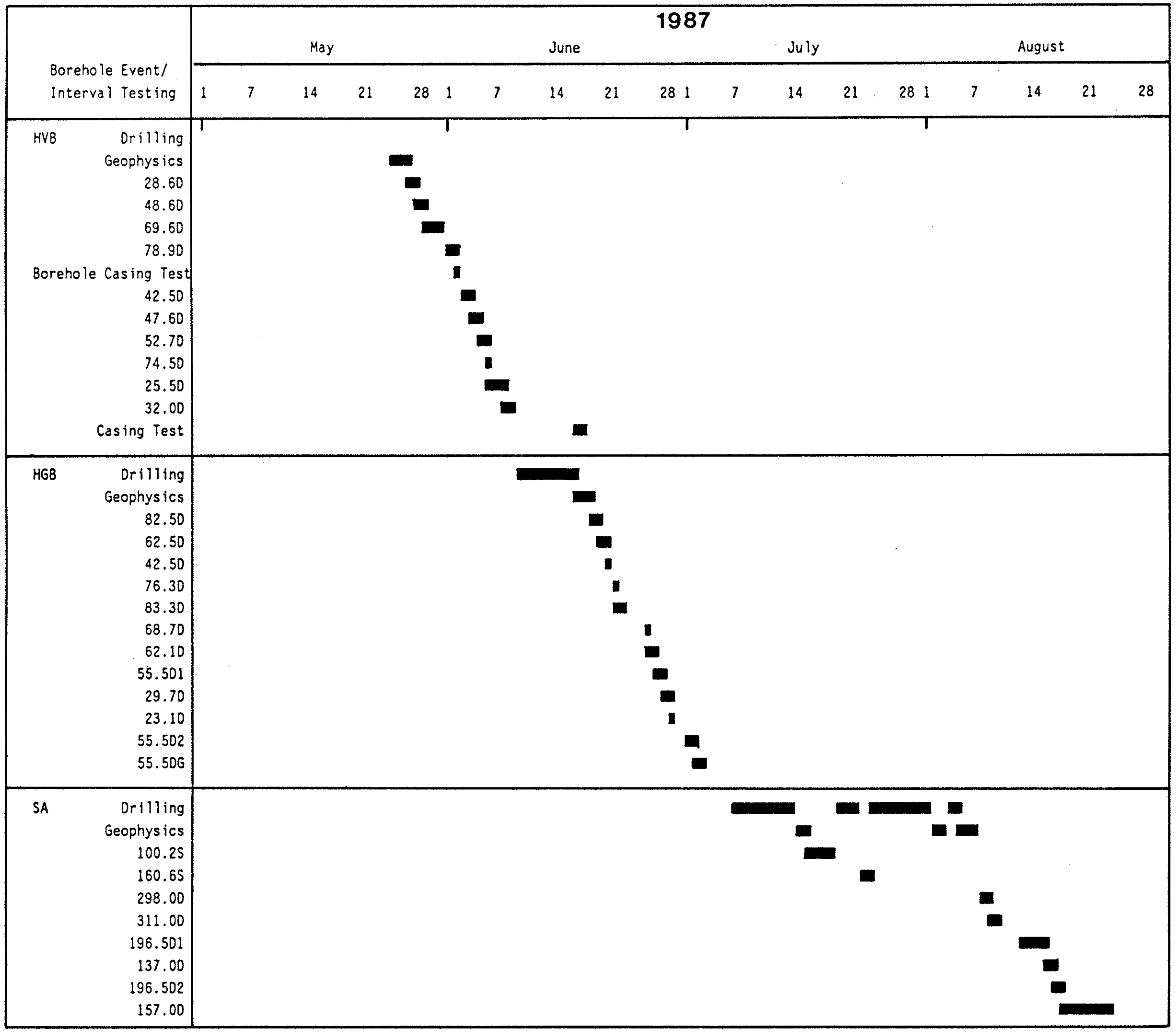

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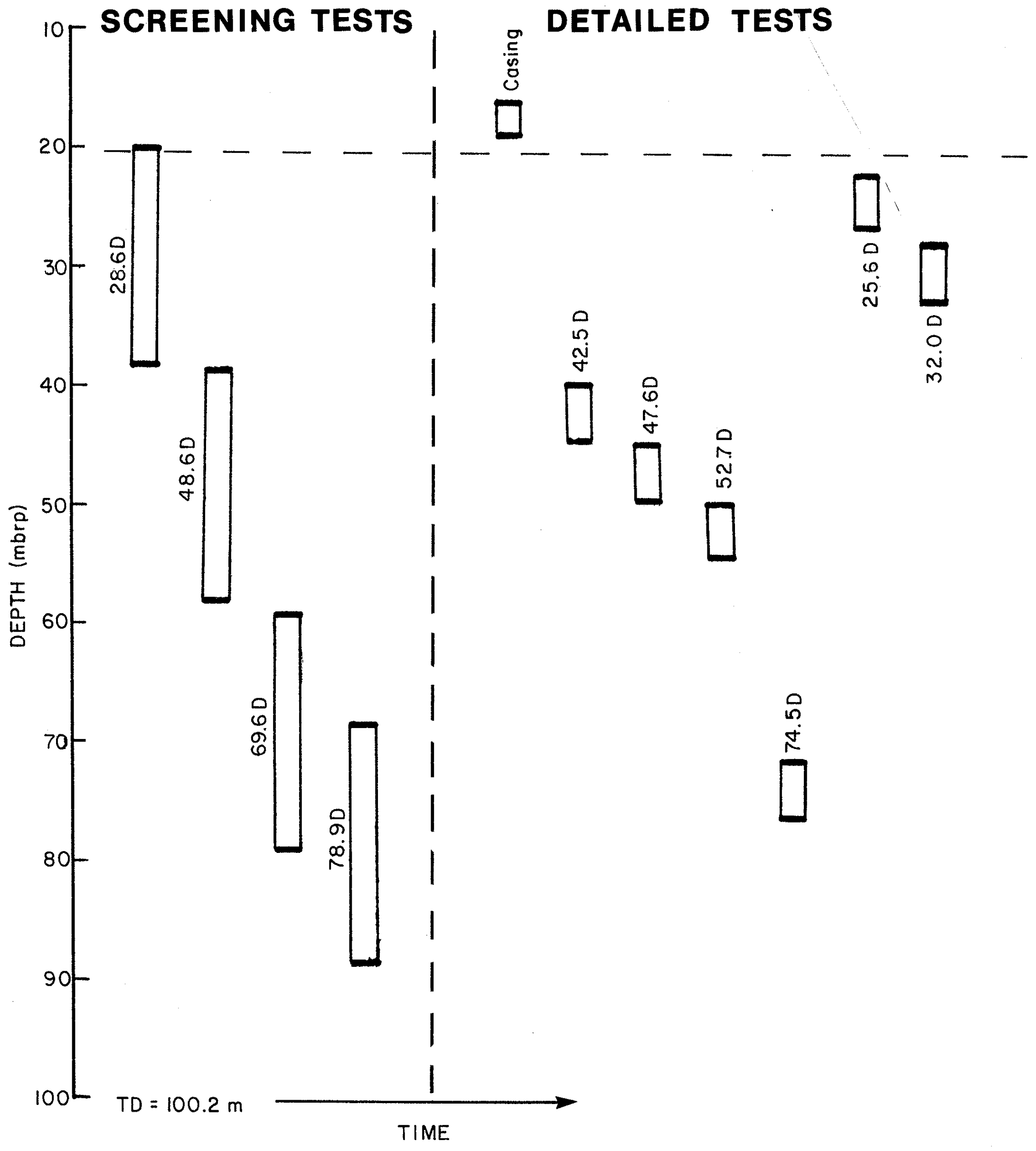
INTERVAL TESTING AND ASSOCIATED ACTIVITIES



NAGRA / GLAG **NTB: 88-03**

HVB TESTING DETAILS

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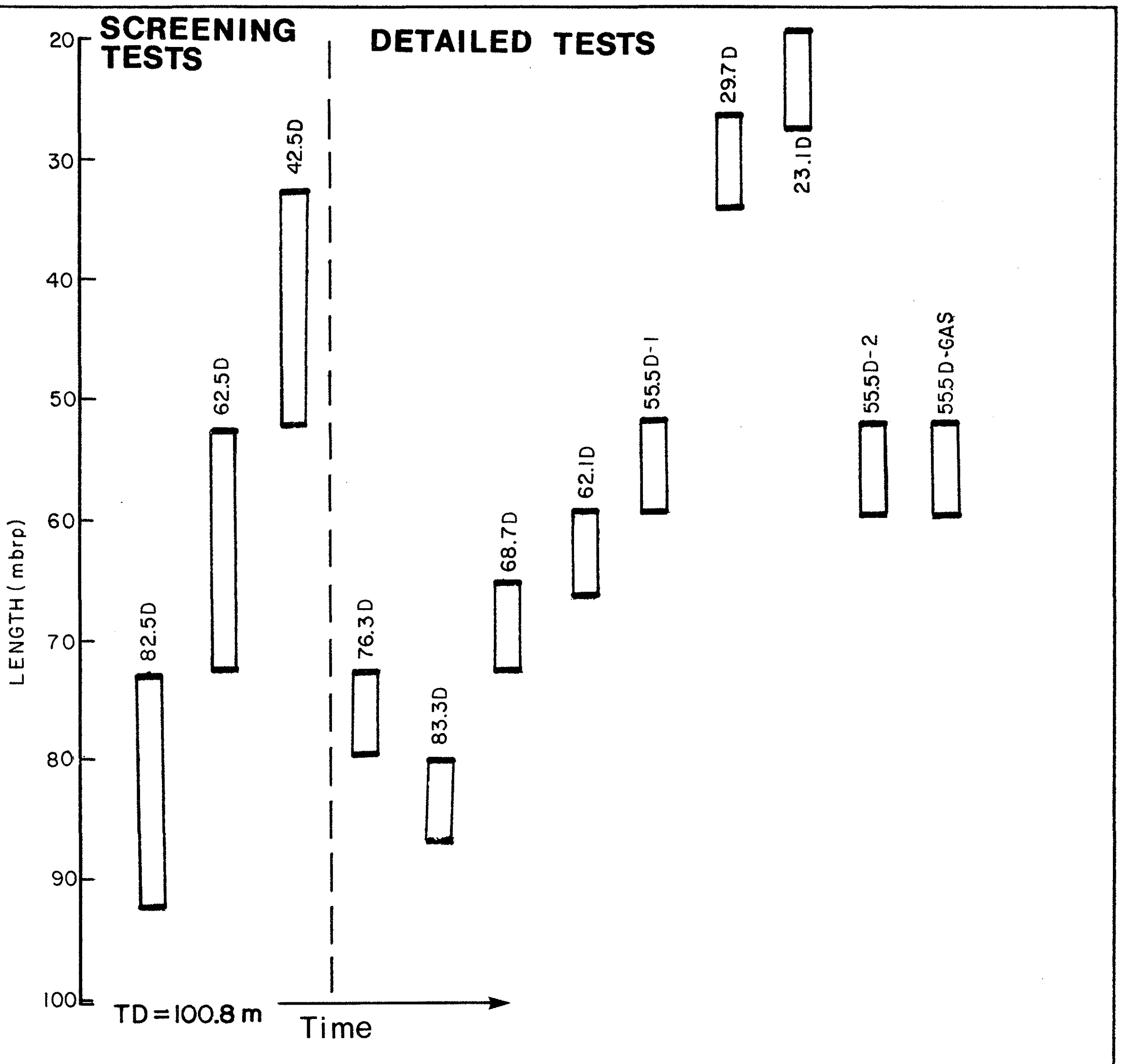

NAGRA/GLAG **NTB:88-03**

HGB TESTING DETAILS

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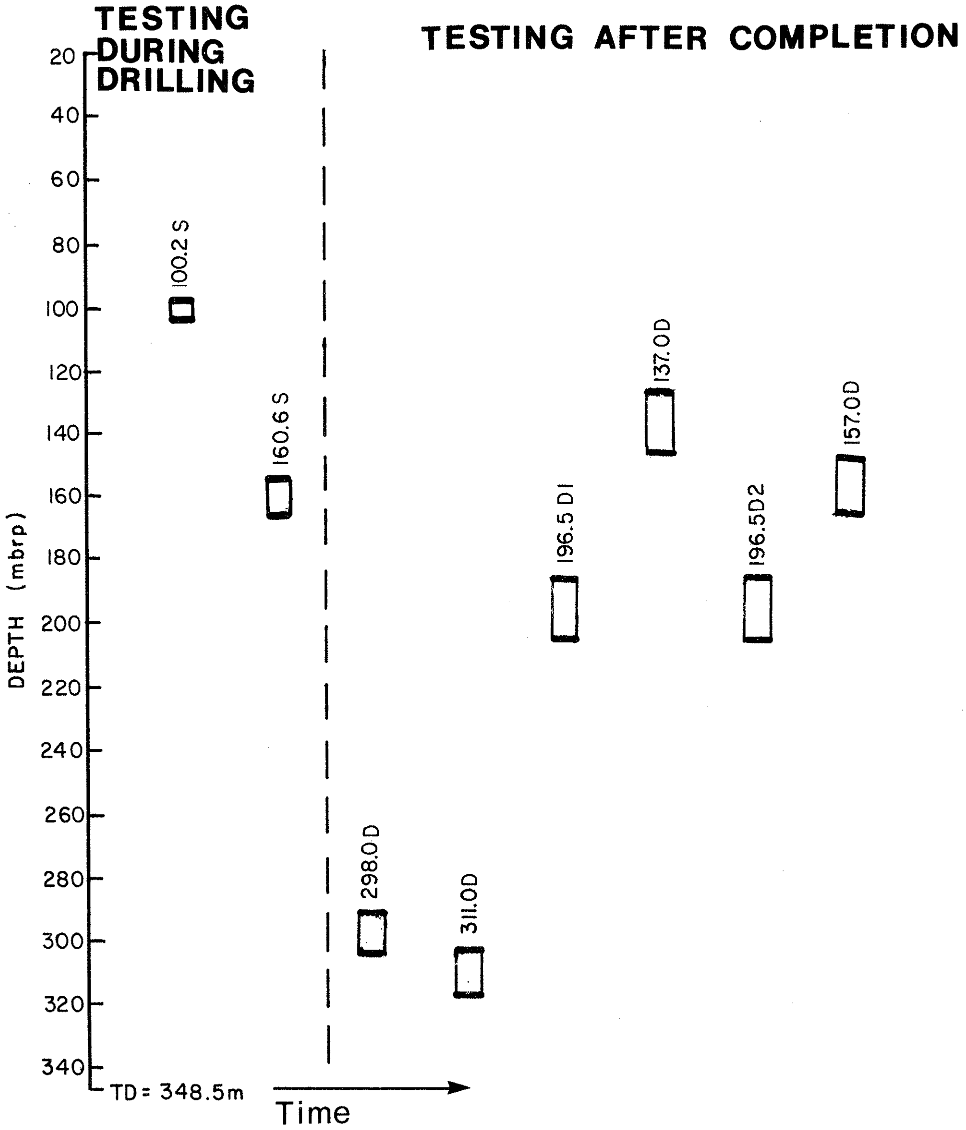

NAGRA / GLAG — NTB: 88-03

SA TESTING DETAILS

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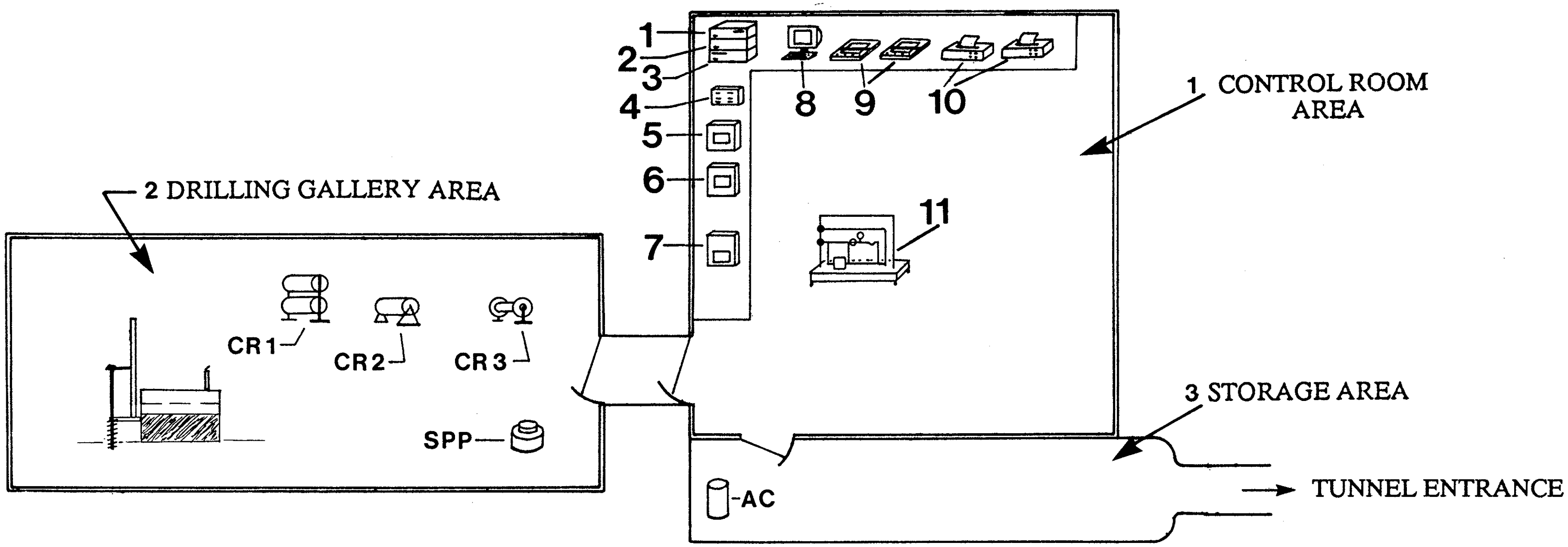


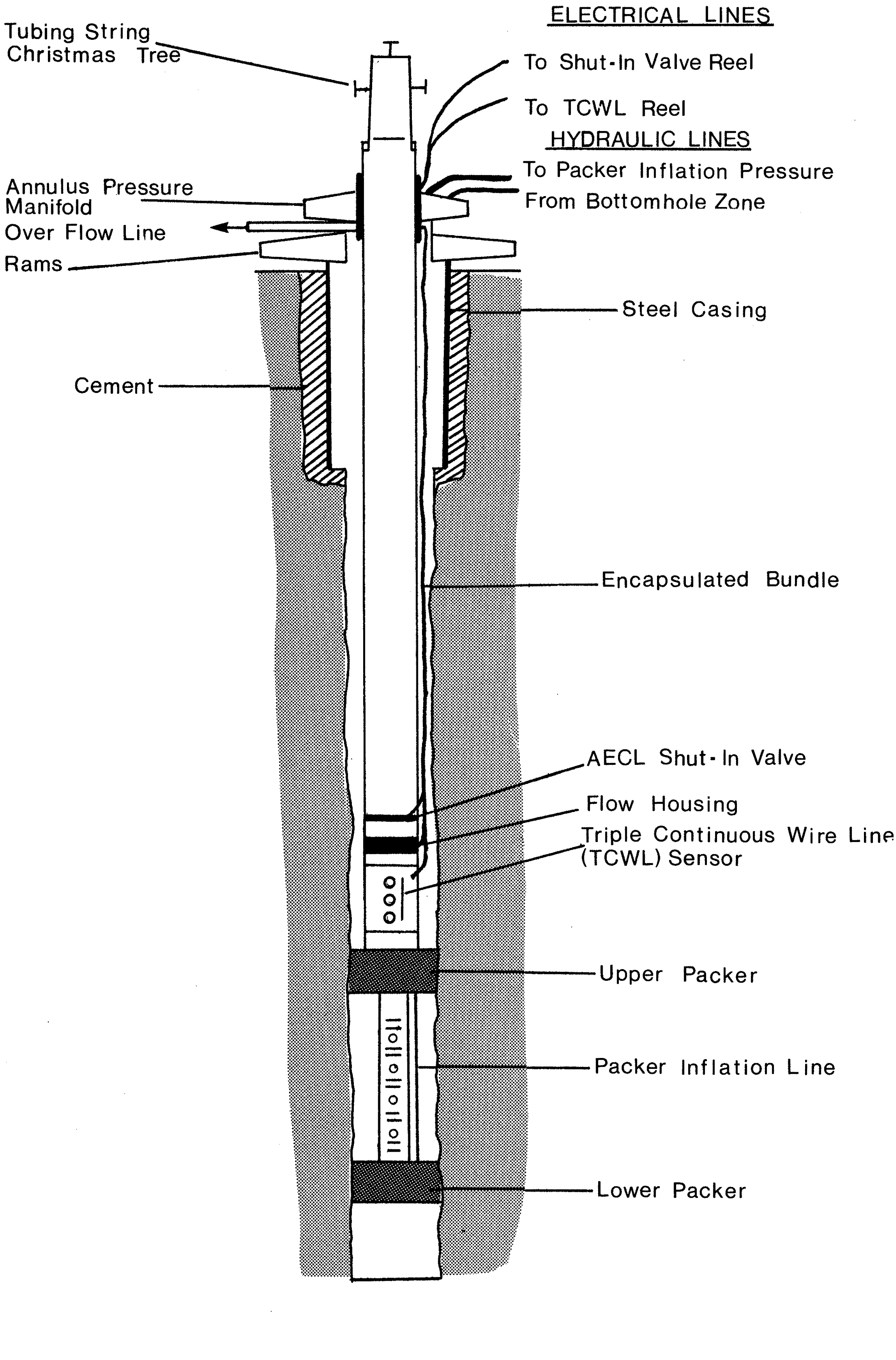
Legend

1	DOS DISK DRIVE	7	FLOW METER PROCESSOR	CR1 -	SHUT-IN VALVE REEL
2	BUS EXPANDER	8	COMPUTER/KEYBOARD	CR2 -	WATER SAMPLING REEL
3	HARD DISK (40 MB)	9	PLOTTERS (2)	CR3 -	TCWL SENSOR REEL
4	SHUT-IN VALVE CONTROL BOX (2)	10	PRINTERS (2)	SPP -	SURFACE PRESSURE PROBE
5	TCWL SC2 BOX/FREQUENCY COUNTER	11.	FLOW MANIFOLD BOARD	AC -	AIR COMPRESSOR
6	SPP SC2 BOX/FREQUENCY COUNTER				

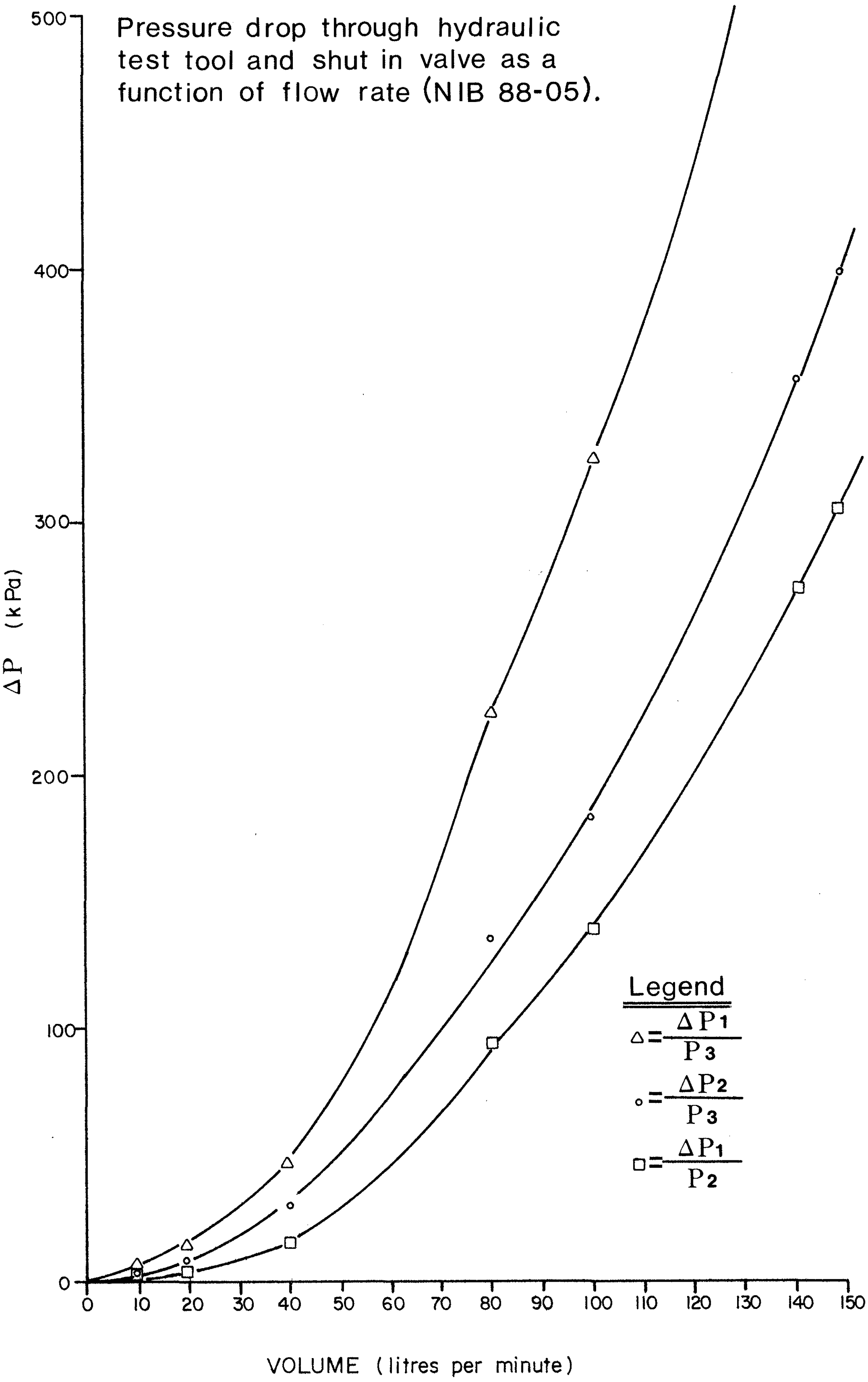
NOTE : See downhole equipment details on Figure 3.2

NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	3.1

HYDROGEOLOGICAL TESTING EQUIPMENT BASIC COMPONENTS



NAGRA / GLAG		NTB: 88-03
DOWNHOLE PACKER ASSEMBLY		
OBERBAUENSTOCK	DAT.: APR. 88	3.2



NAGRA / **GLAG** **NTB:88-03**

PRESSURE DROP THROUGH THE DOWNHOLE TESTING EQUIPMENT

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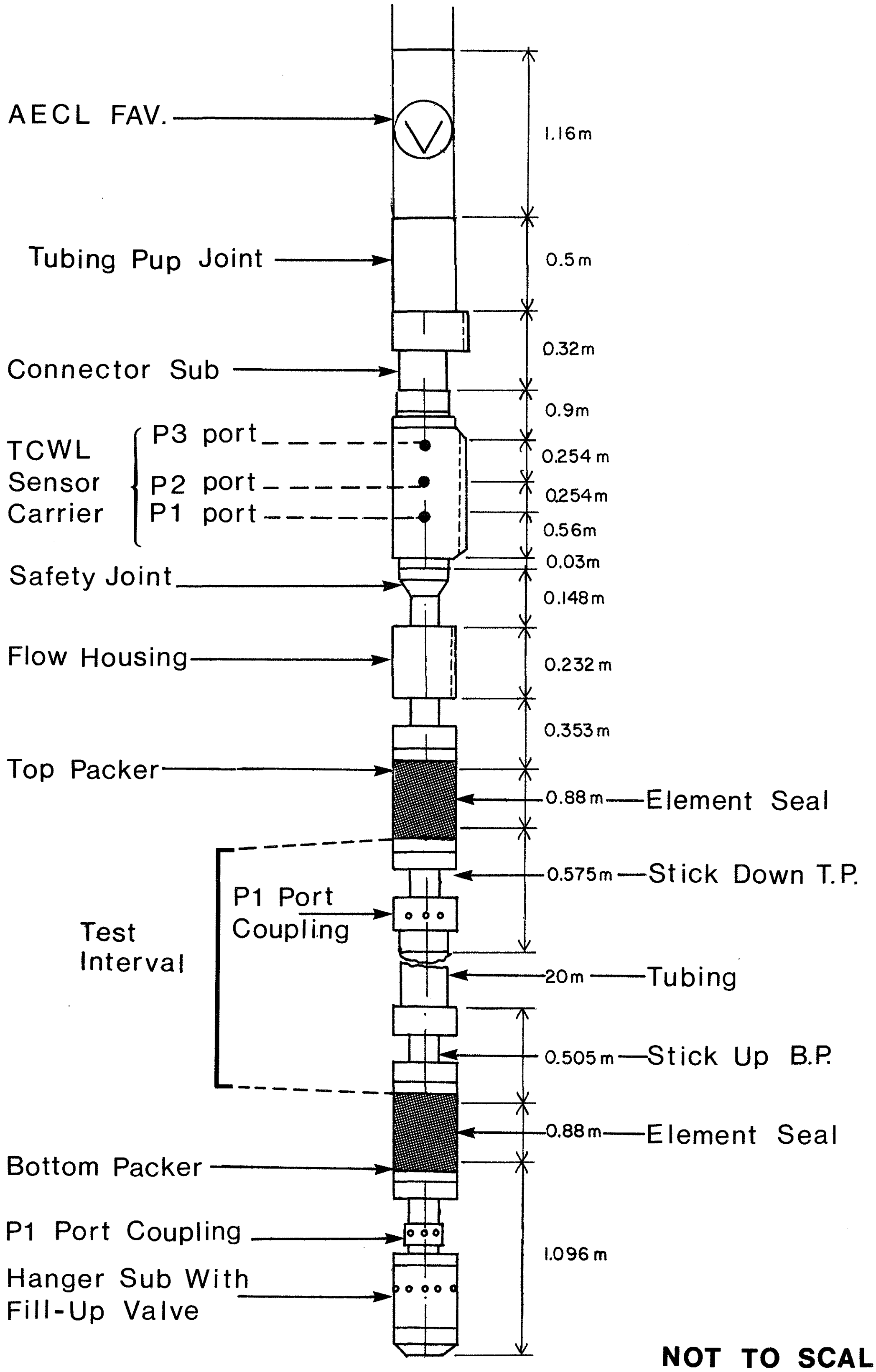


NOT TO SCALE

NAGRA/GLAG	**NTB: 88-03**

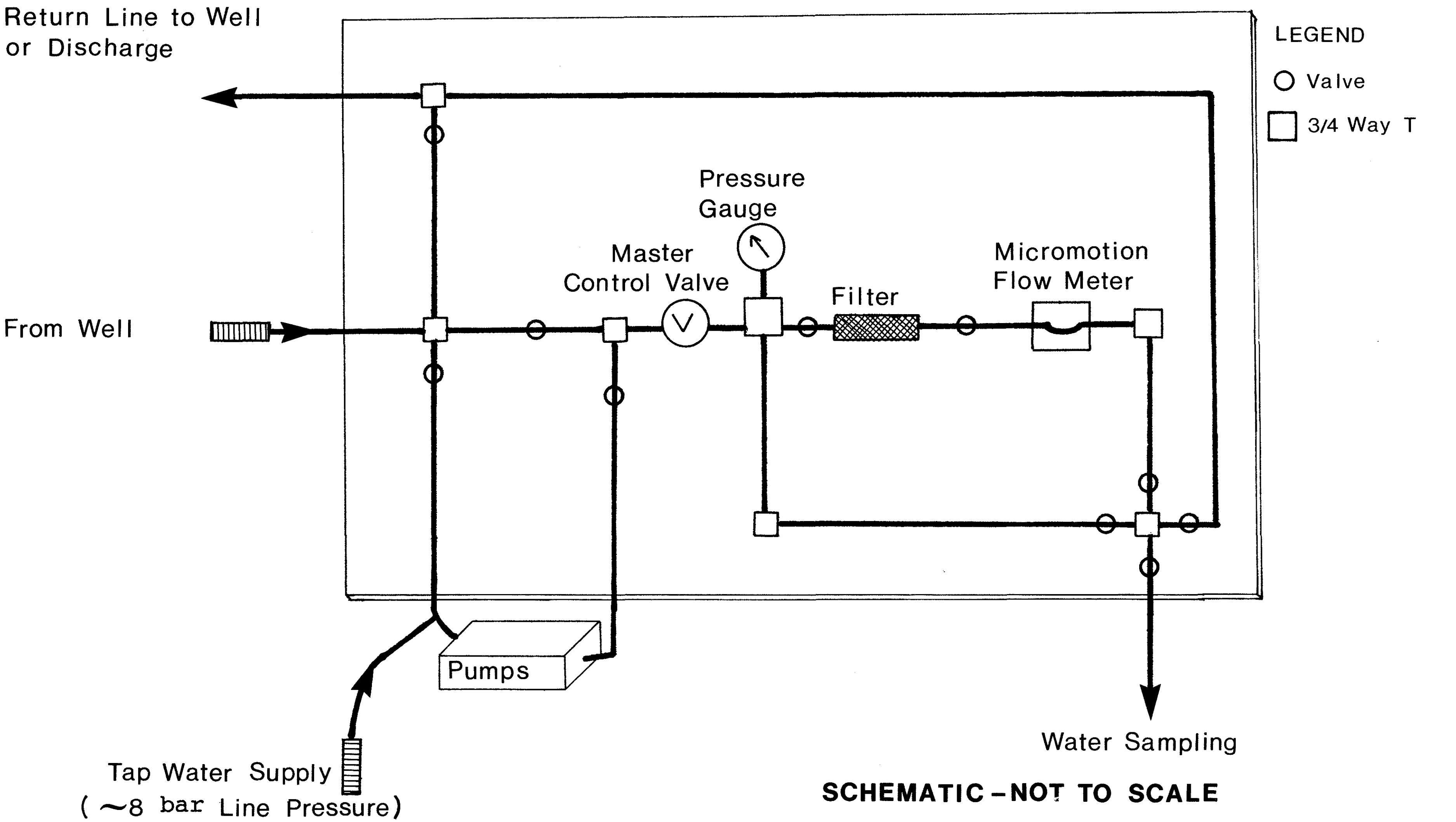
TYPICAL DOWNHOLE ASSEMBLY CONFIGURATION

OBERBAUENSTOCK	DAT.: APR. 88	3.4

OBS2/62.5D/ ① ·21 Jun 87 Day 172 Page 4 **Flow Meter**

② Time	③ TCWL DATA P1 KPA	P2 KPA	P3 KPA	T1 C	T2 C	T3 C	④ SINGLE PS KPA	TS C	⑤ Flow	Total
02:30:11.488									000266. gm/min	00002985.
02:30:14.625							5556.74	19.89		
02:30:00.885	139.77	821.06	466.96	17.01	17.15	16.55				
02:30:26.030									000281. gm/min	00003049.
02:30:30.614									000265. gm/min	00003070.
02:30:41.168									000262. gm/min	00003116.
02:30:30.445	139.77	823.75	466.86	17.01	17.15	16.55				
02:31:00.695									000264. gm/min	00003203.
02:31:11.230									000268. gm/min	00003250.
02:31:00.885	139.77	824.01	466.86	17.01	17.15	16.55				
02:31:20.781									000258. gm/min	00003293.
02:31:31.326									000255. gm/min	00003339.
02:31:40.882									000264. gm/min	00003381.
02:31:30.365	139.77	825.09	466.86	17.01	17.15	16.55				
02:31:51.445									000266. gm/min	00003428.
02:32:00.985									000273. gm/min	00003470.
02:32:11.522									000280. gm/min	00003517.
02:32:00.785	139.90	828.13	466.86	17.01	17.15	16.55				
02:32:21.044									000277. gm/min	00003560.
02:32:30.597									000269. gm/min	00003602.
02:32:41.120									000267. gm/min	00003649.
02:32:30.225	139.90	829.74	466.96	17.01	17.15	16.55				
02:32:50.651									000253. gm/min	00003691.
02:33:06.193									000269. gm/min	00003761.
02:33:10.785									000263. gm/min	00003781.
02:33:00.705	139.77	831.34	466.96	17.01	17.16	16.55				
02:33:21.316									000261. gm/min	00003828.
02:33:40.851									000274. gm/min	00003915.
02:33:30.145	139.77	833.04	466.96	17.01	17.16	16.55				
02:33:51.423									000262. gm/min	00003961.
02:34:00.965									000262. gm/min	00004004.
02:34:11.490									000266. gm/min	00004051.
02:34:00.525	139.90	835.91	466.86	17.01	17.16	16.55				
02:34:21.052									000262. gm/min	00004093.
02:34:35.602									000271. gm/min	00004135.
02:34:41.101									000282. gm/min	00004160.
02:34:30.925	139.77	837.60	466.96	17.01	17.16	16.55				
02:34:50.612									000253. gm/min	00004182.
02:35:01.149									000257. gm/min	00004224.
02:35:10.718									000271. gm/min	00004270.
02:35:10.772							5557.09	19.89		
02:35:00.405	139.77	838.41	466.96	17.01	17.16	16.55				
02:35:21.234									000280. gm/min	00004312.
02:35:31.391									000274. gm/min	00004359.
02:36:00.938									000259. gm/min	00004405.
02:36:00.885	139.64	837.33	466.86	17.01	17.16	16.55				
02:36:31.463									000280. gm/min	00004536.
02:37:00.973									000263. gm/min	00004673.
02:37:00.265	139.77	846.28	467.05	17.01	17.17	16.55				
02:37:30.544									000272. gm/min	00004805.
02:38:01.045									000287. gm/min	00004938.

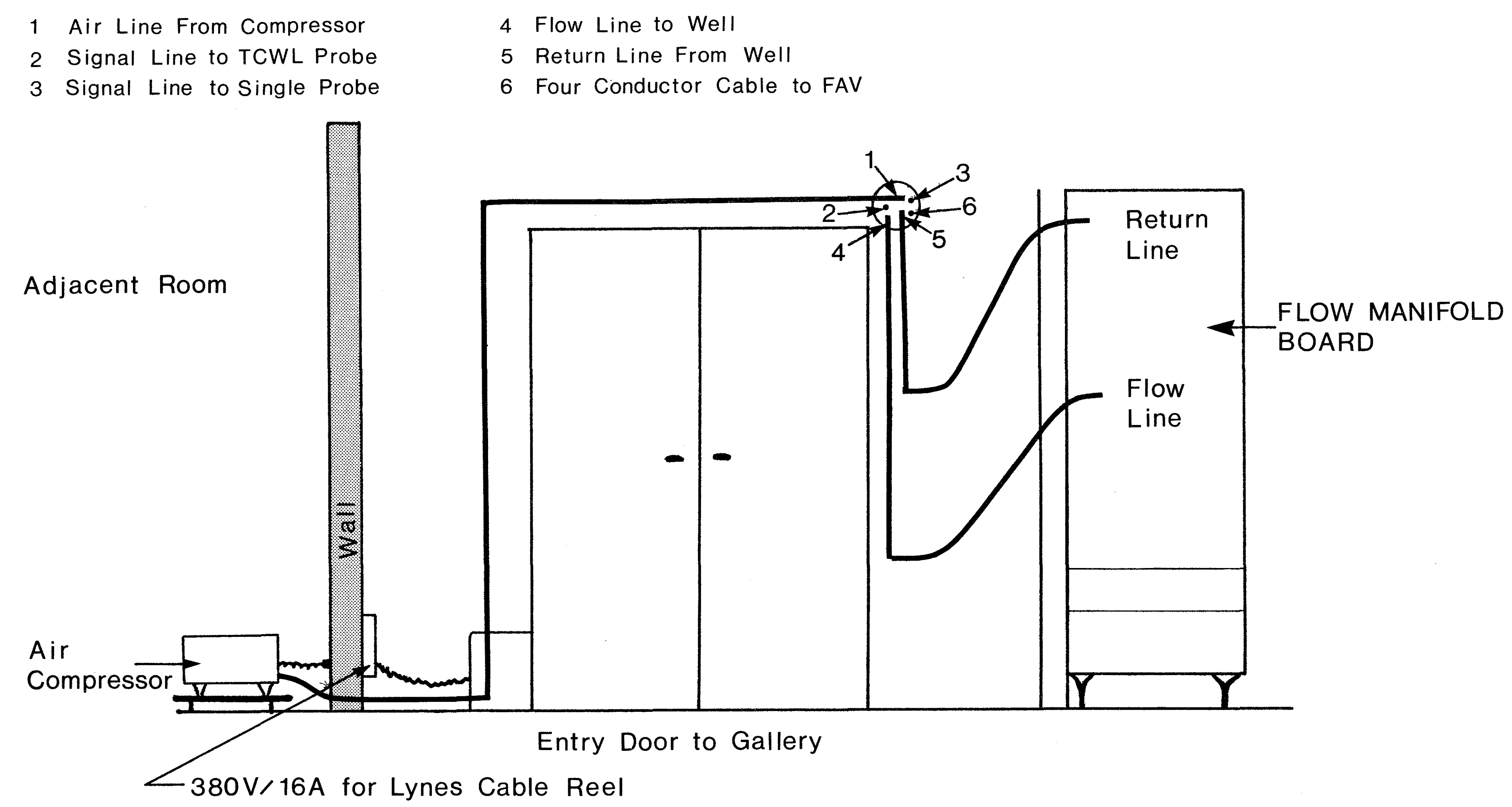
① Header for test, date
② Time of day of readings
③ Downhole pressure & temperature data
④ Surface probe pressure & temperature data
⑤ Flow meter rate & totalizer data



SCHEMATIC – NOT TO SCALE

NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	3.6 (a)

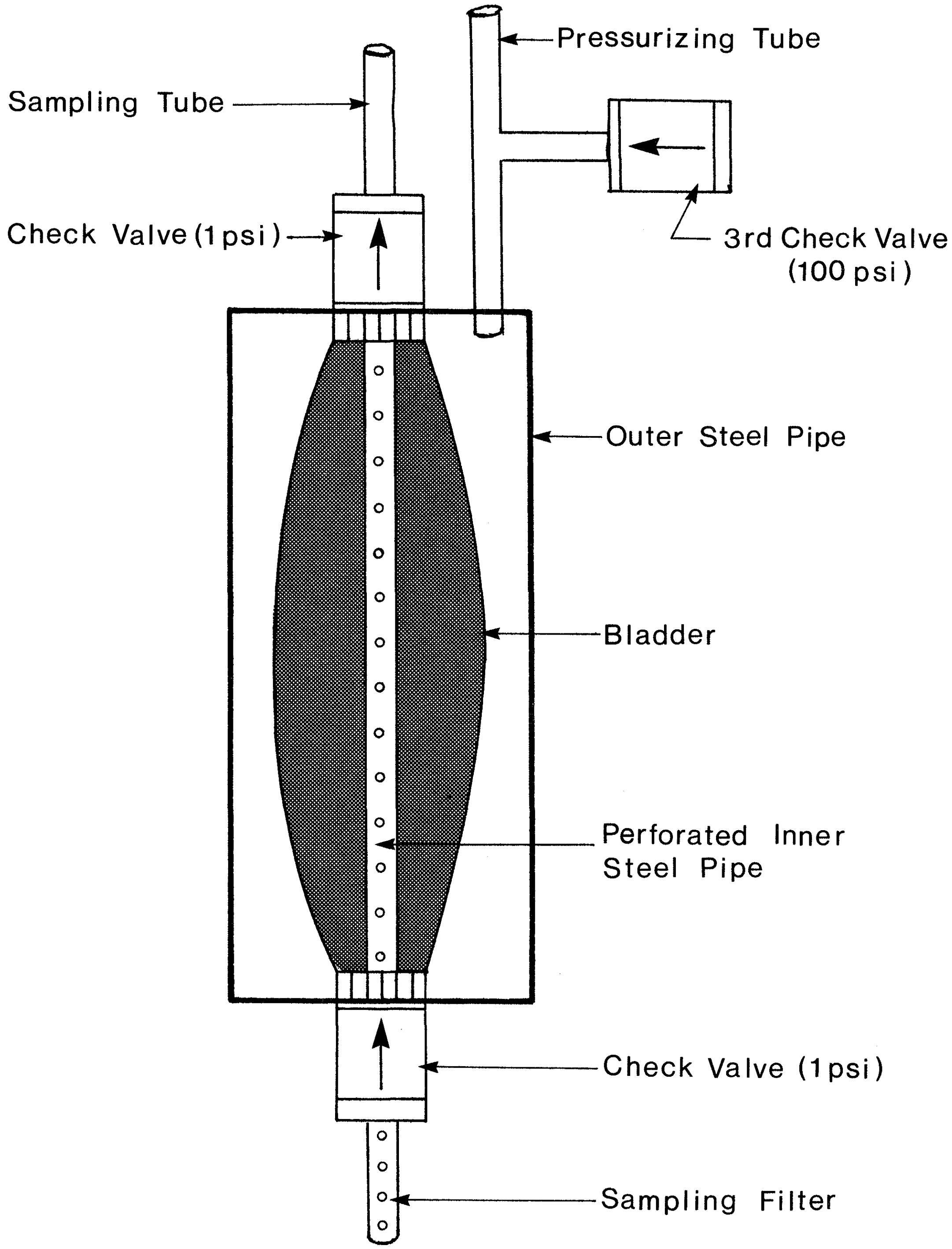
FLOW MANIFOLD BOARD LAYOUT



SCHEMATIC-NOT TO SCALE

NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	3.6 (b)

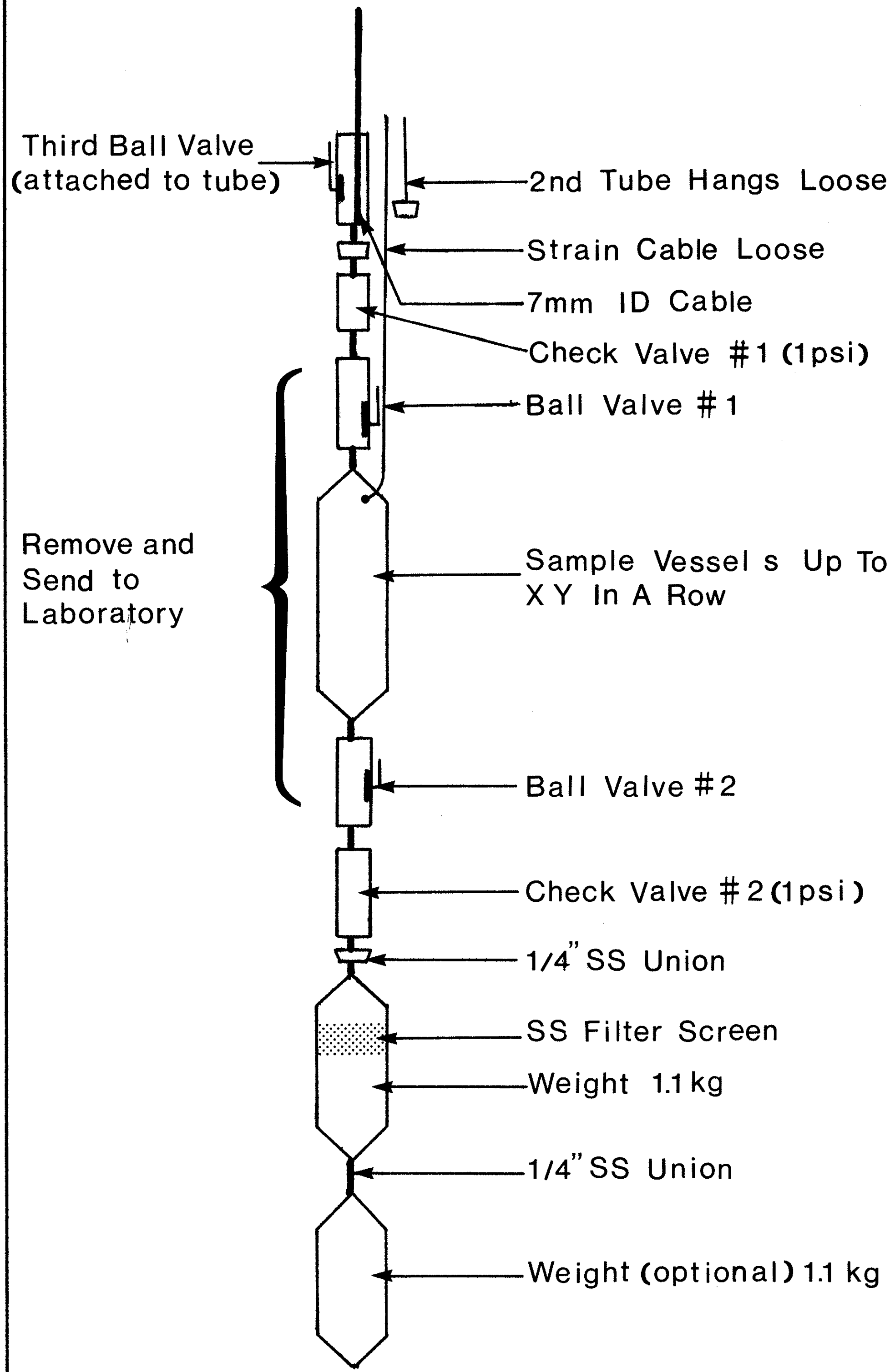
CONTROL ROOM HYDRAULIC AND ELECTRONIC CABLE LAYOUT



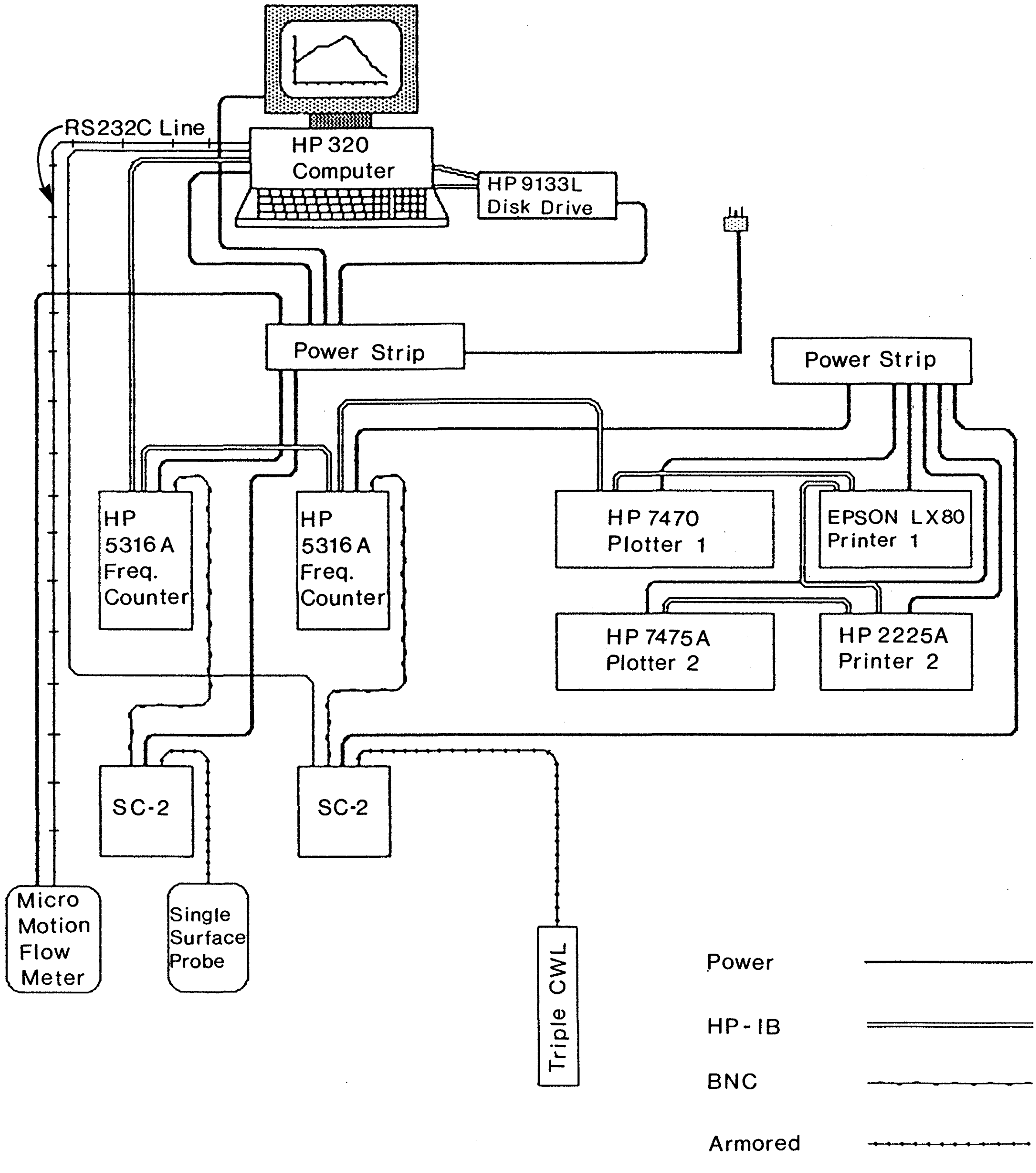
NAGRA / GLAG NTB: 88-03

SQUEEZE PUMP SCHEMATIC

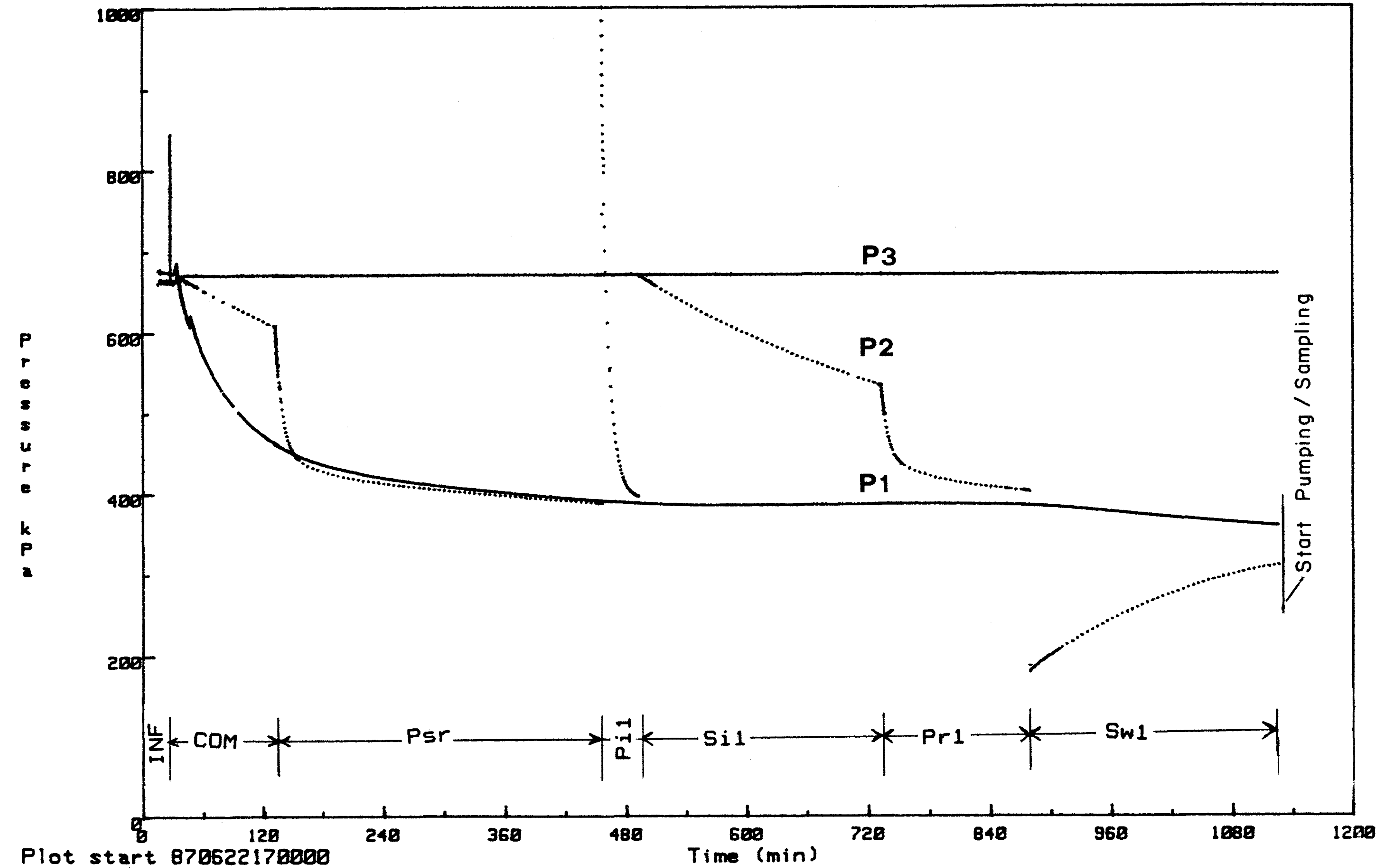
OBERBAUENSTOCK	DAT.: APR. 88	3.7



NAGRA / GLAG		NTB: 88-03
PRESSURIZED SAMPLE VESSEL SCHEMATIC		
OBERBAUENSTOCK	DAT.: APR. 88	3.8

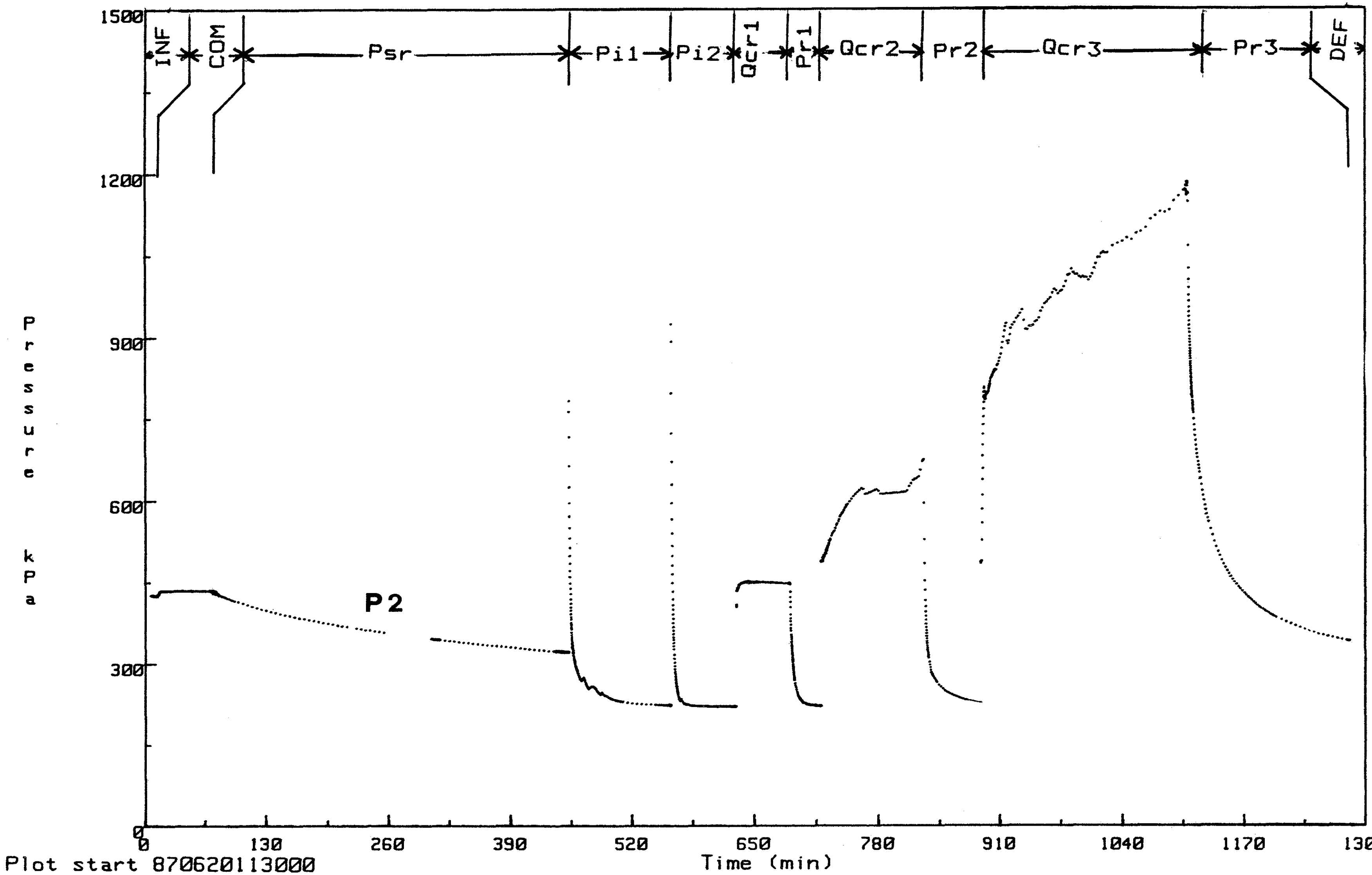


NAGRA / GLAG		NTB: 88-03
DATA PROCESSING SYSTEM SCHEMATIC		
OBERBAUENSTOCK	DAT.: APR. 88	3.9



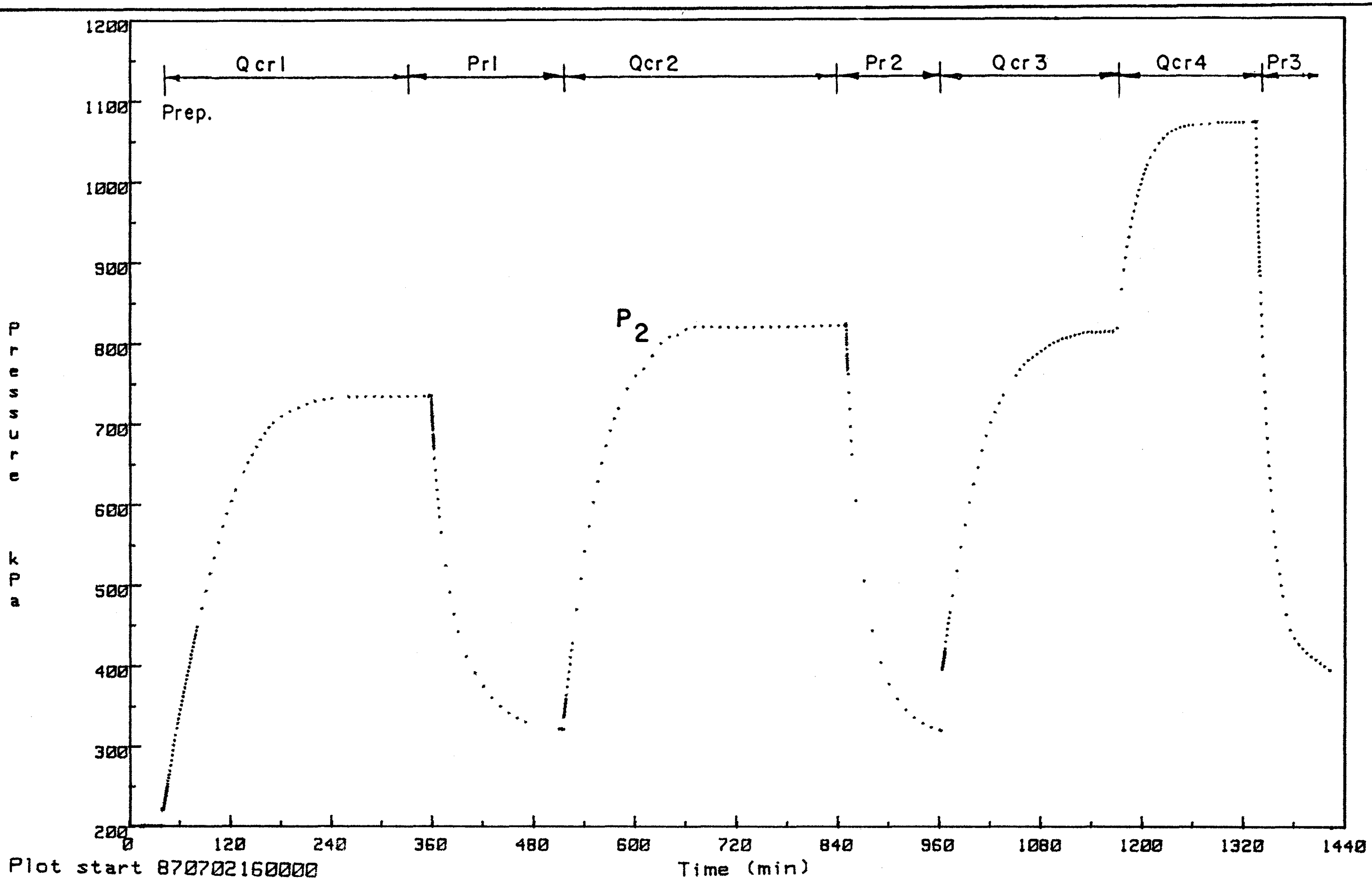
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	3.10

EXAMPLE EVENT RESPONSES



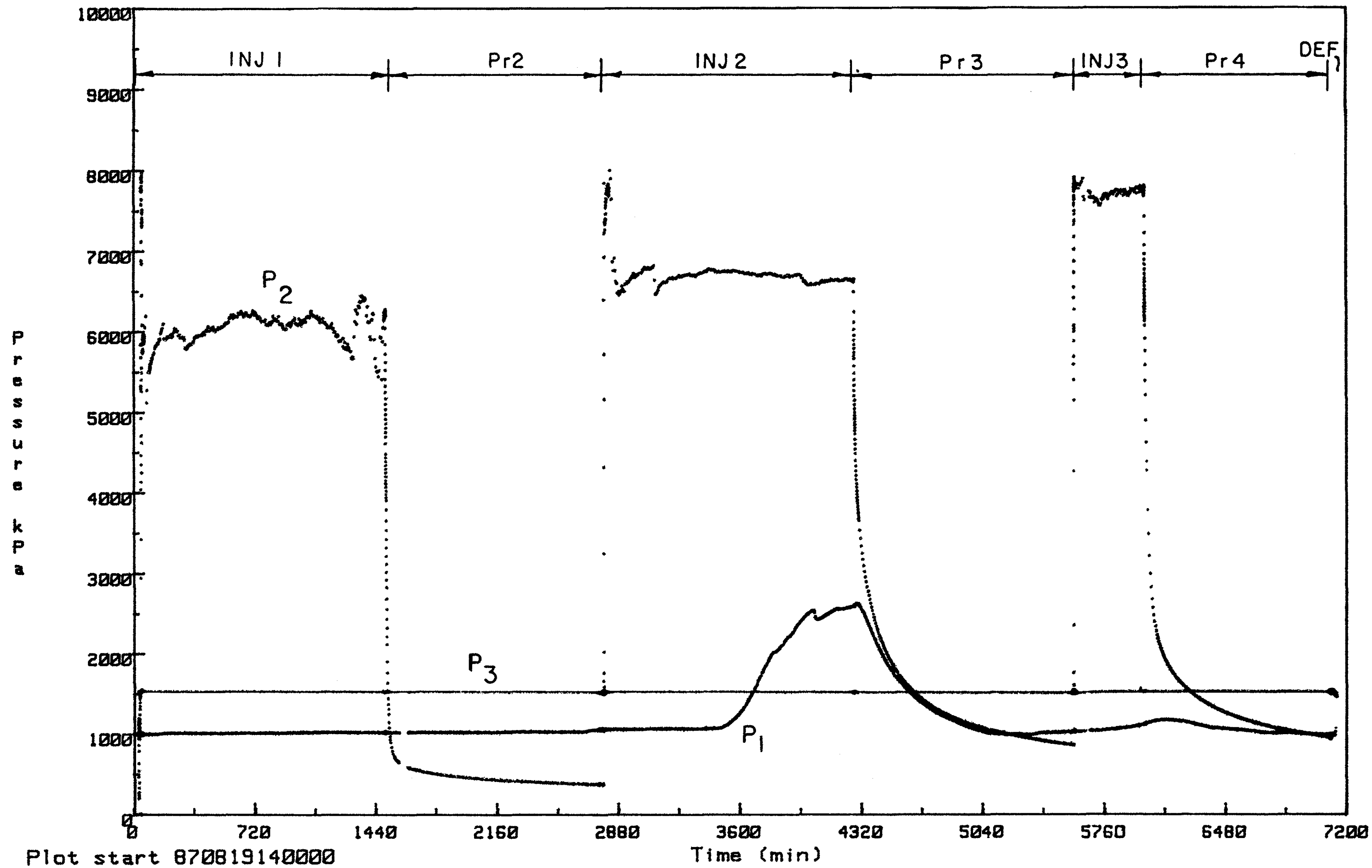
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 3.11

EXAMPLE CONSTANT RATE INJECTION TEST RESPONSE HGB/62.5D



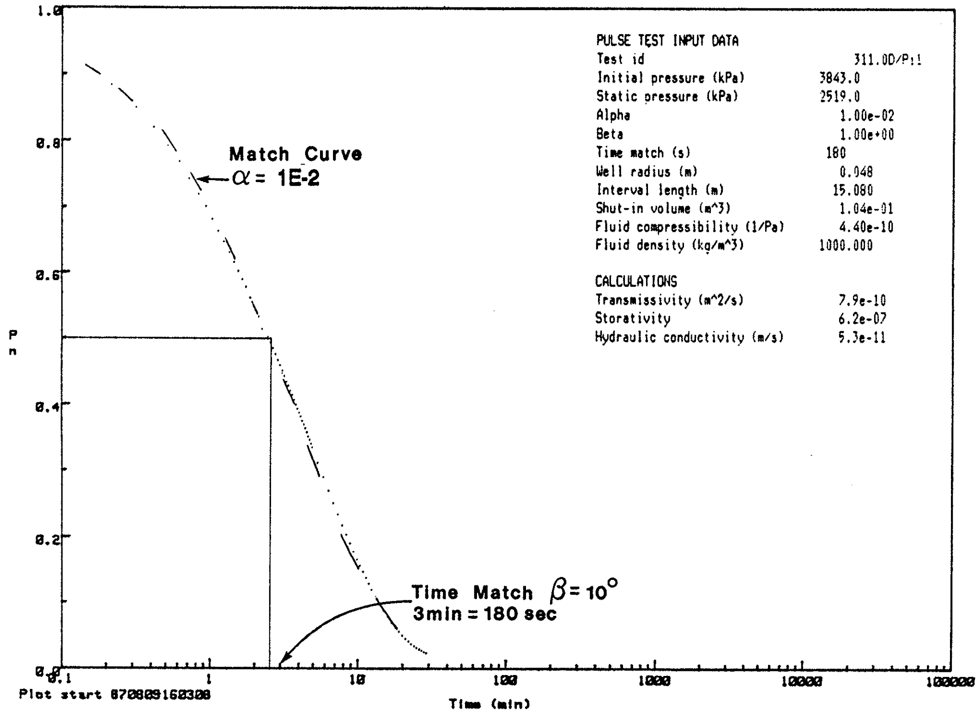
NAGRA / **GLAG** | **NTB: 88-03** | **OBERBAUENSTOCK** | DAT.: APR. 88 | 3.12

EXAMPLE CONSTANT RATE INJECTION TEST RESPONSE HGB/55.5D (GAS)



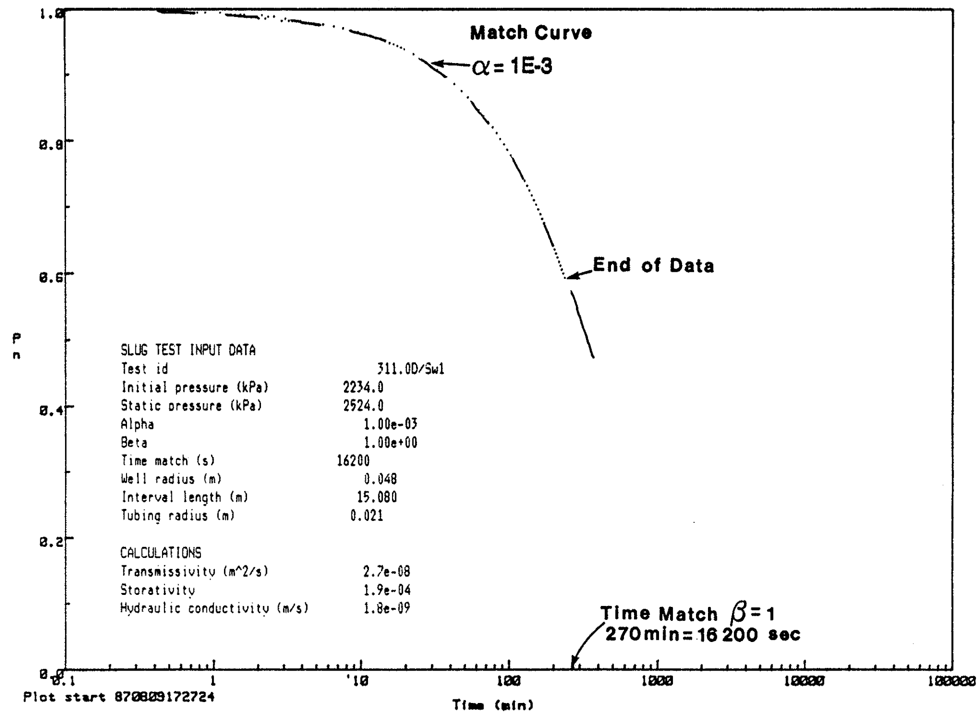
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	3.13

EXAMPLE CONSTANT PRESSURE TEST RESPONSE SA/157.0D



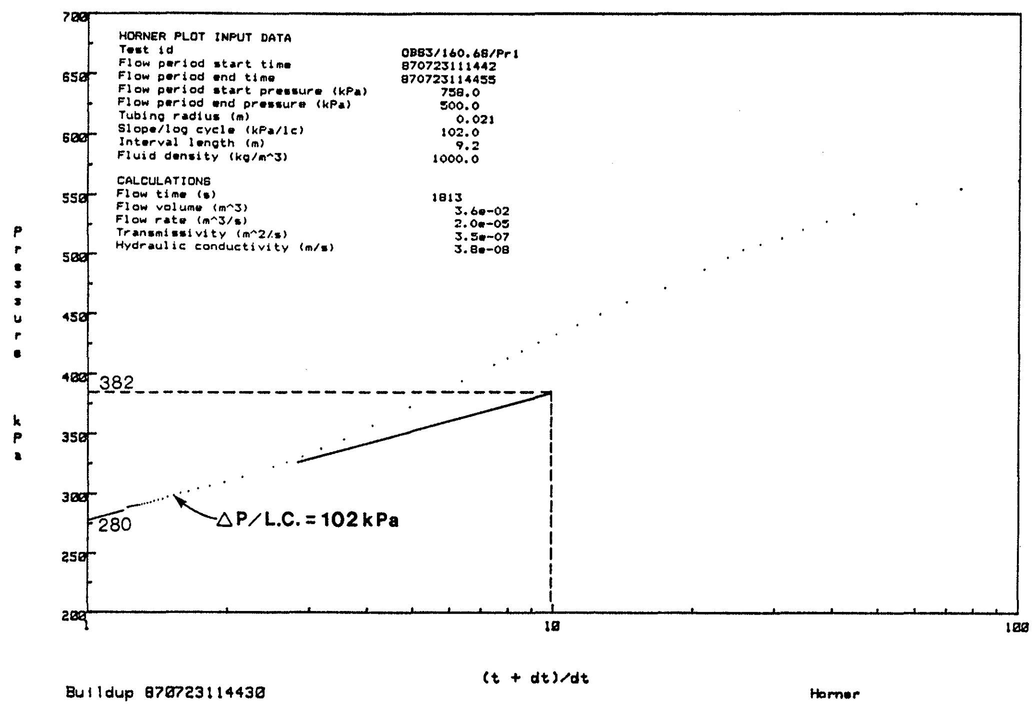
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 4.1 (a)

FIELD ANALYSIS EXAMPLE - PULSE EVENT



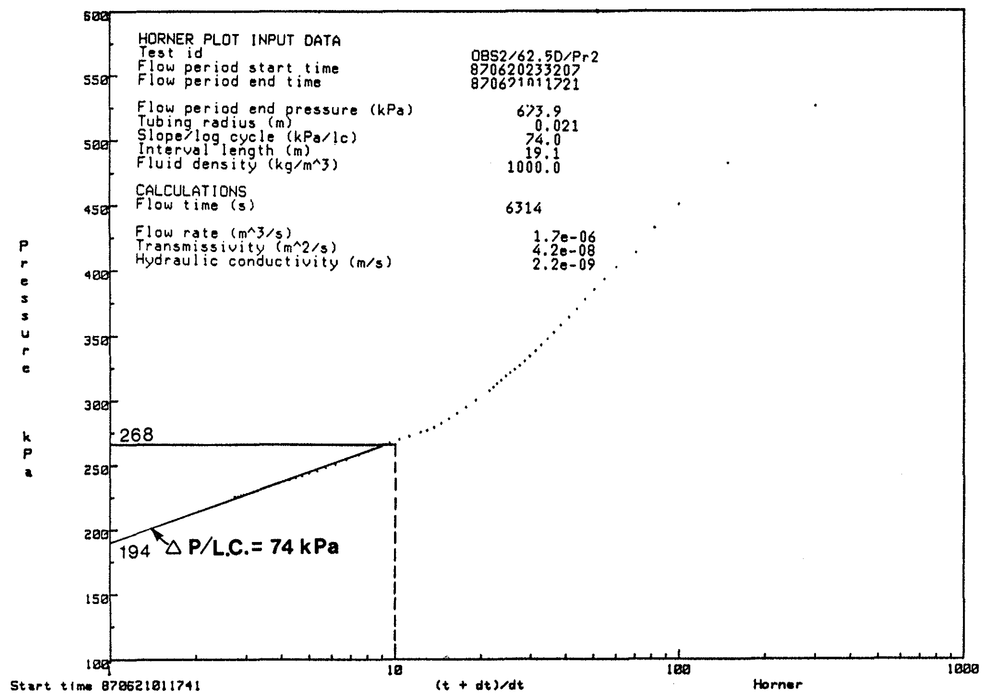
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 4.1 (b)

FIELD ANALYSIS EXAMPLE - SLUG EVENT



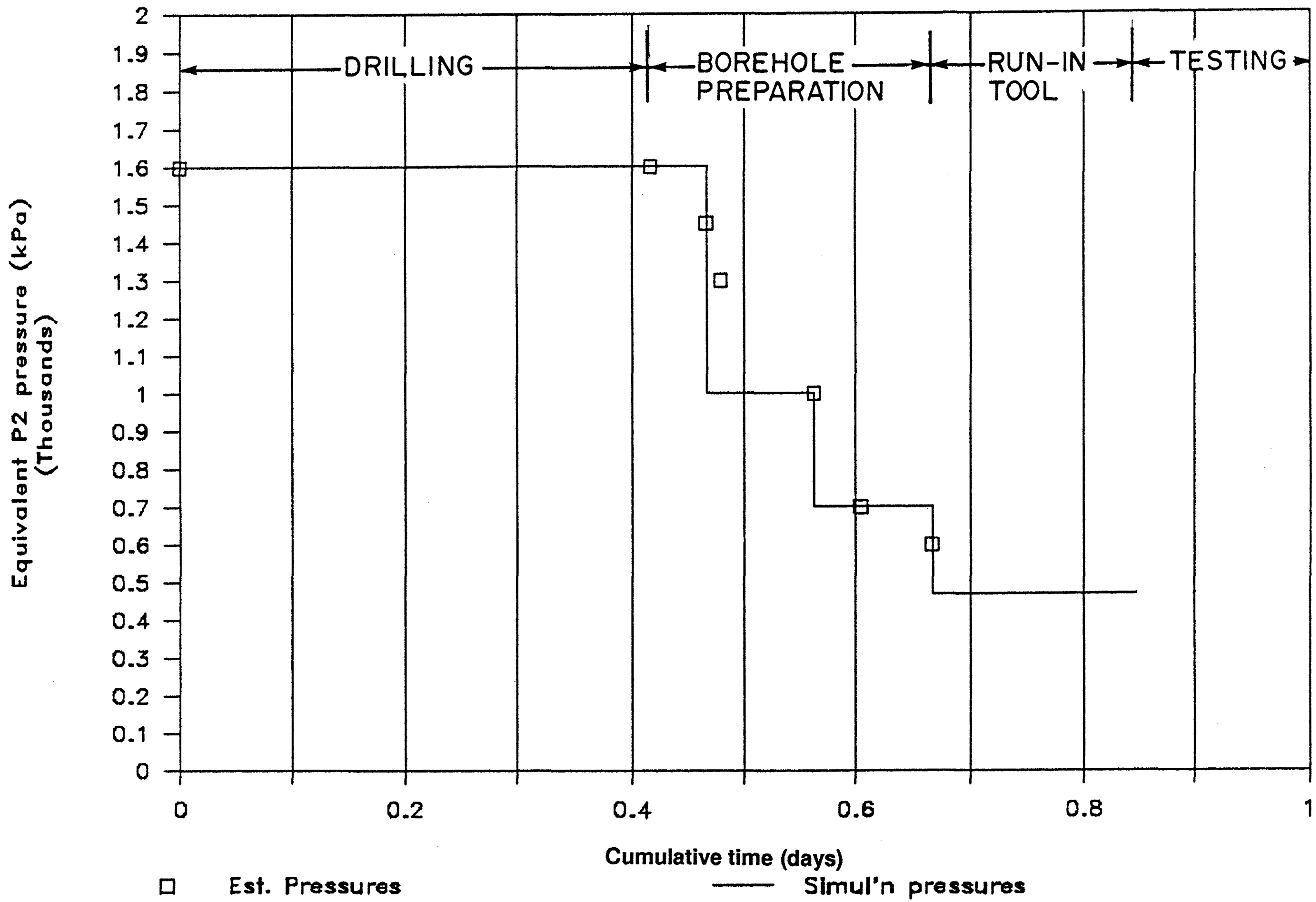
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 4.1 (c)

FIELD ANALYSIS EXAMPLE - HORNER PLOT AFTER SLUG FLOW



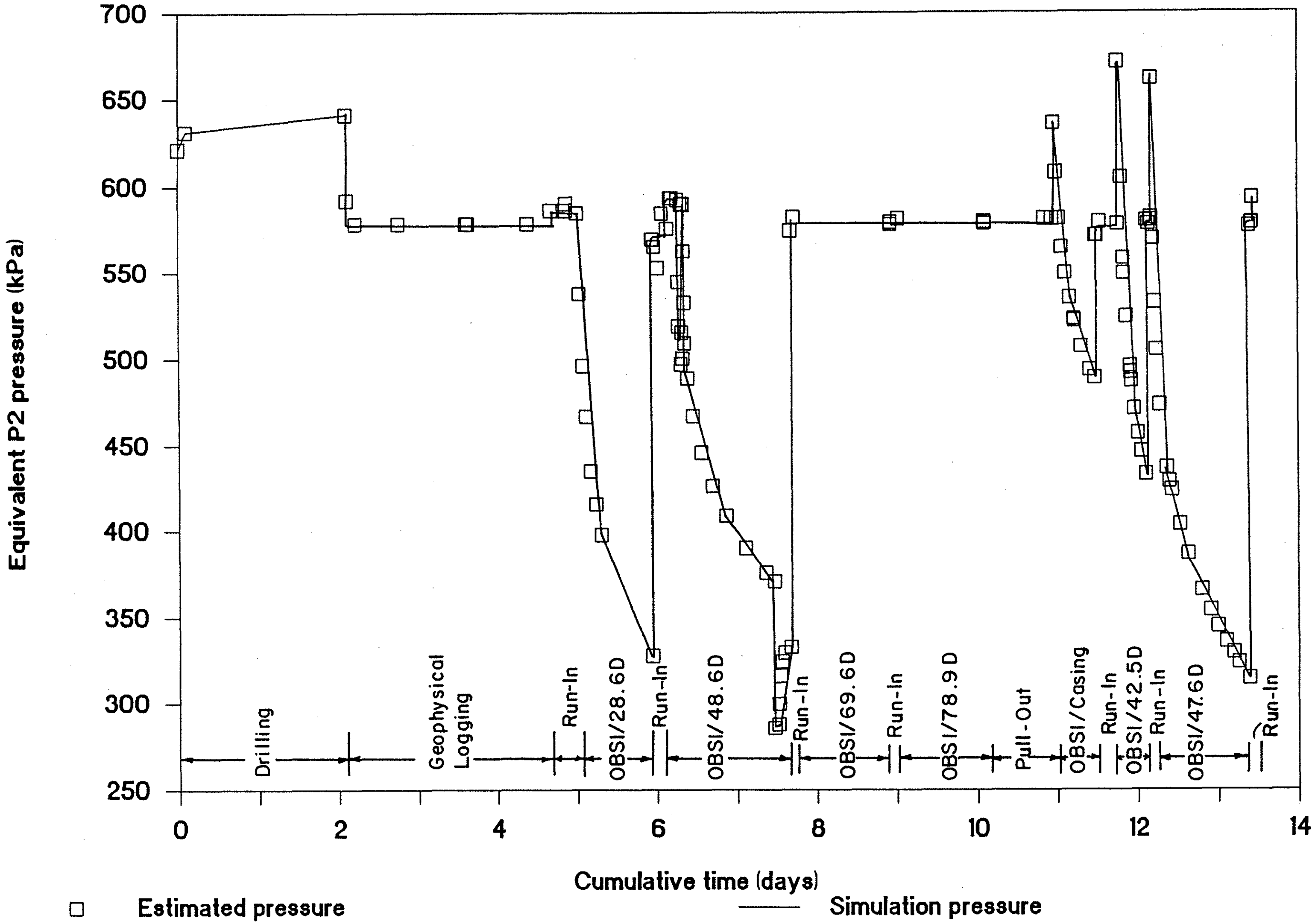
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 4.1 (d)

FIELD ANALYSIS EXAMPLE - HORNER PLOT AFTER CONSTANT RATE INJECTION



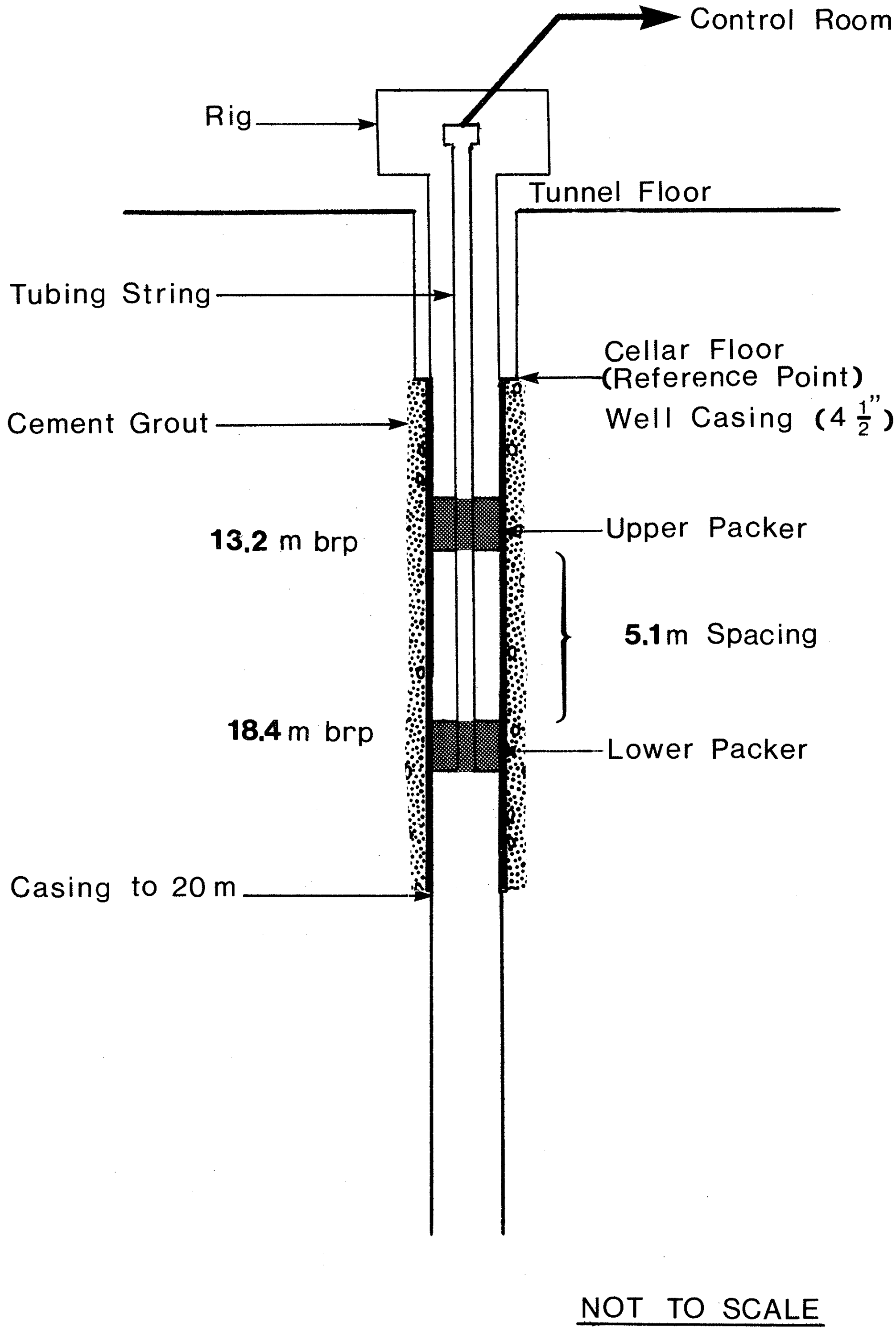
NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	4.2 (a)

SIMPLE BOREHOLE HISTORY, SA/160.6S



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	4.2 (b)

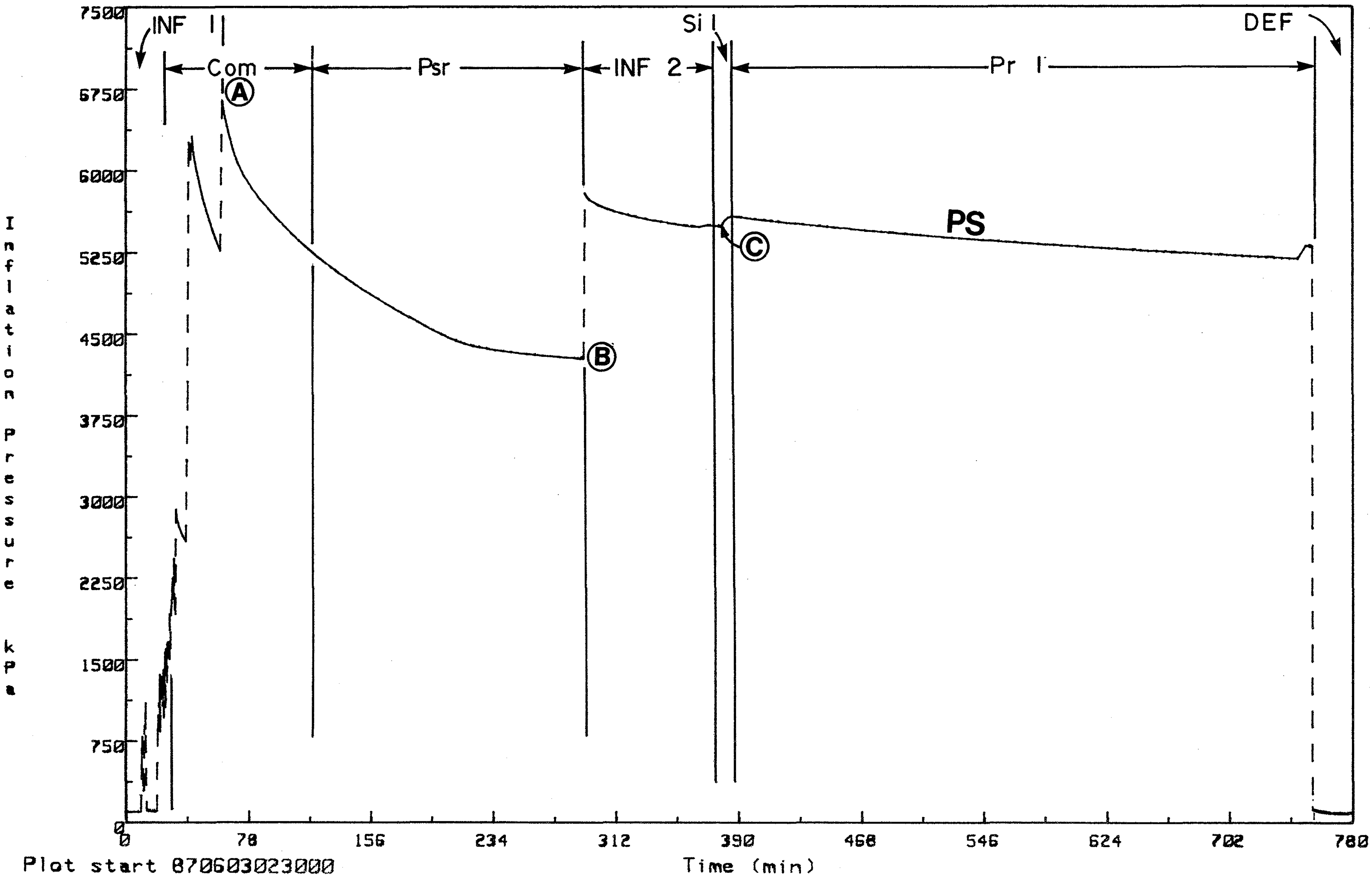
COMPLEX BOREHOLE HISTORY, HVB/52.7D



NAGRA / GLAG NTB:88-03

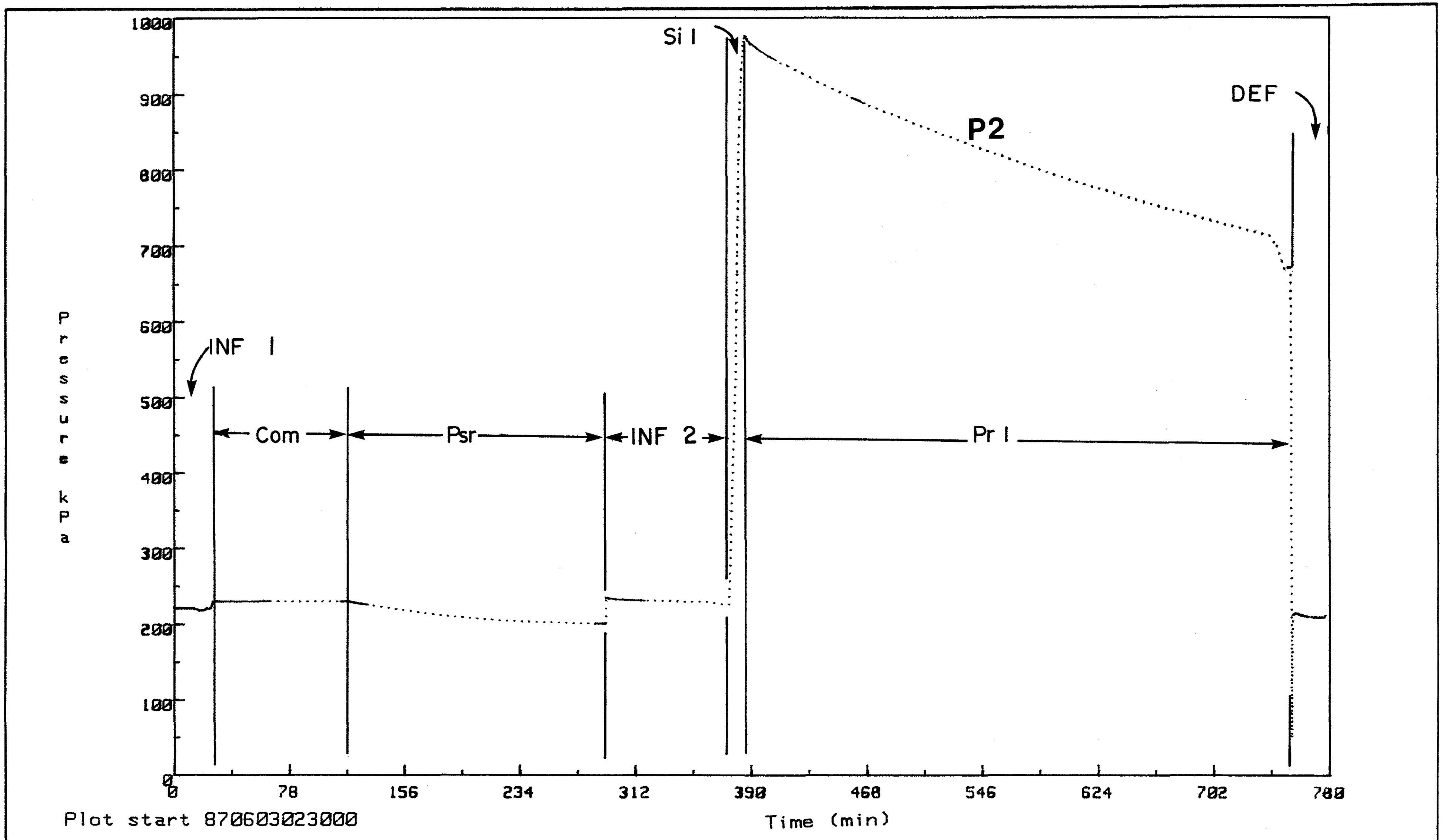
CASING TEST 1 CONFIGURATION

OBERBAUENSTOCK | DAT.: APR. 88 | 5.1



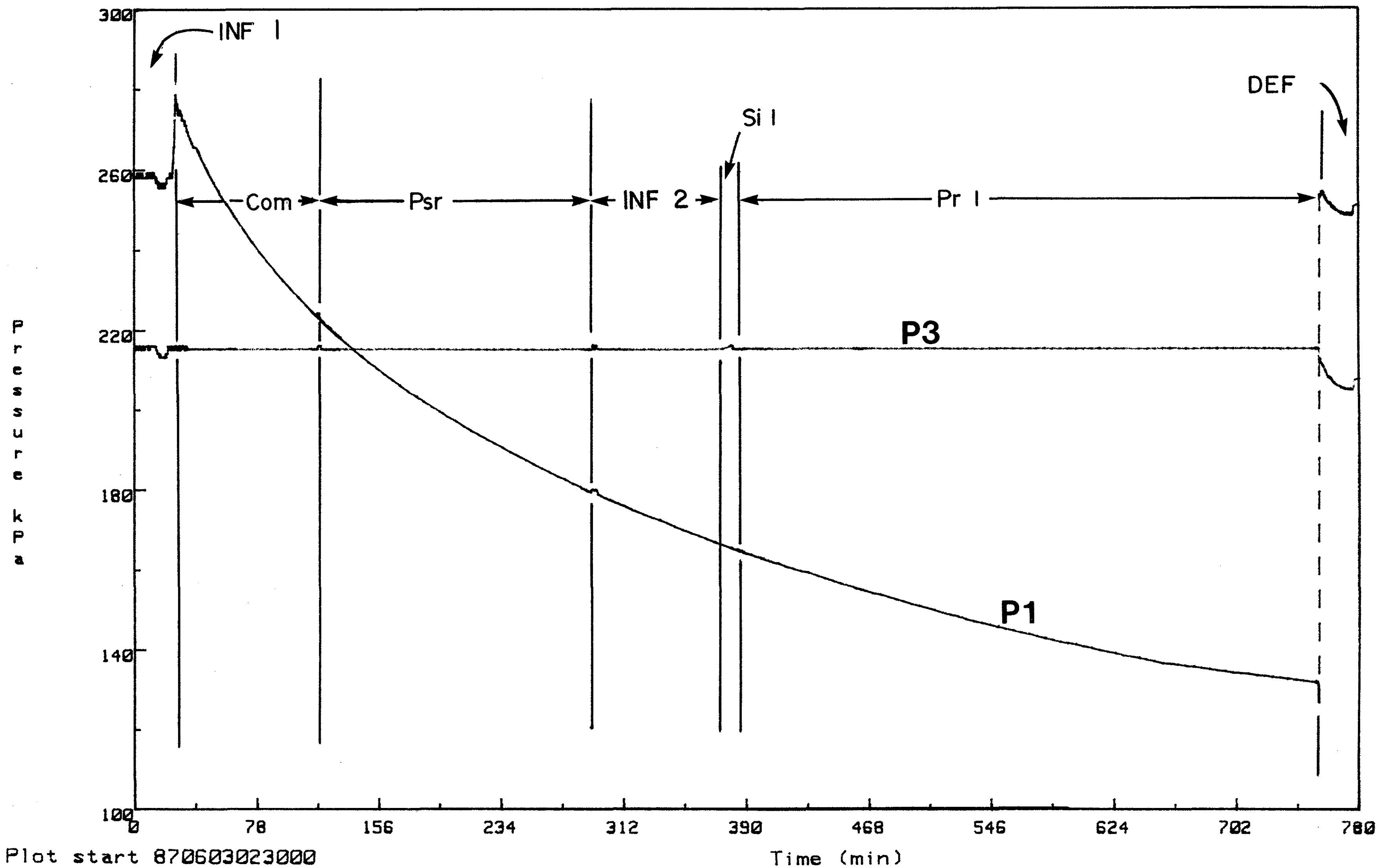
NAGRA / GLAG NTB:88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.2

CASING TEST 1 INFLATION PRESSURE RESPONSE



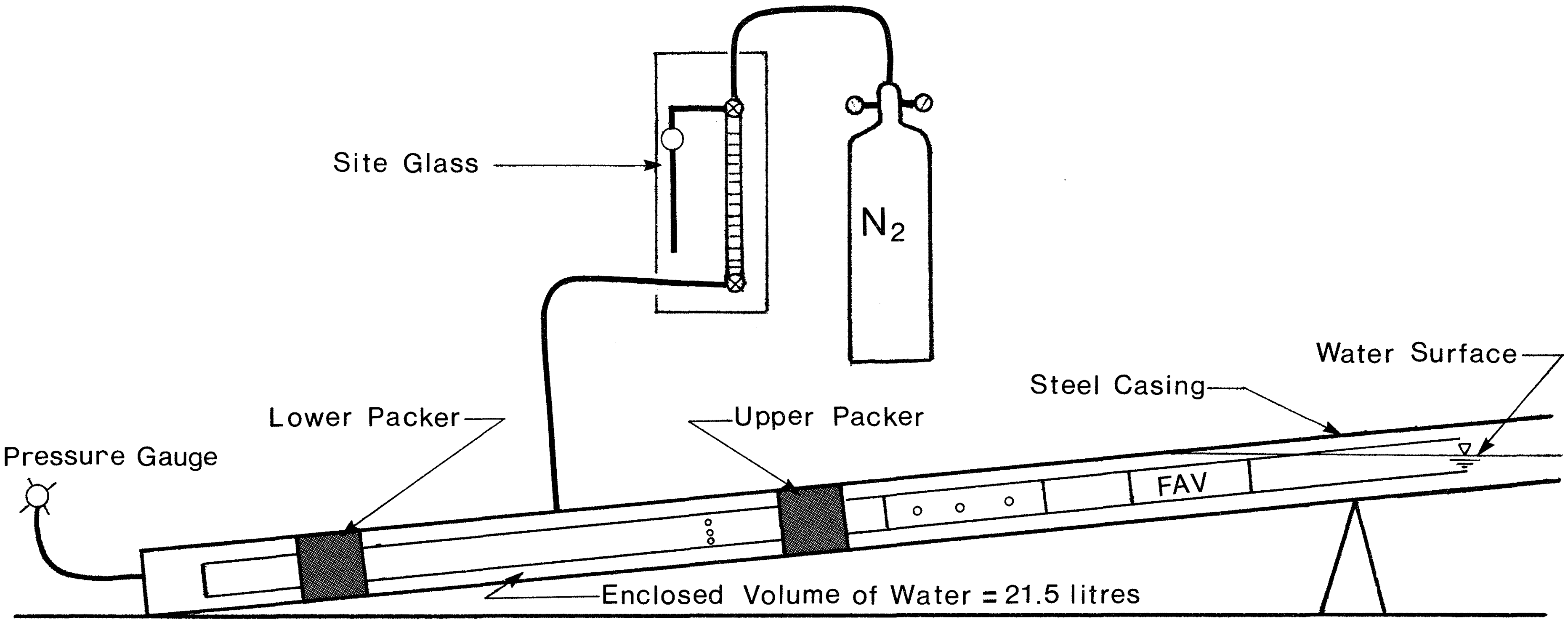
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.3

CASING TEST 1 INTERVAL PRESSURE RESPONSE



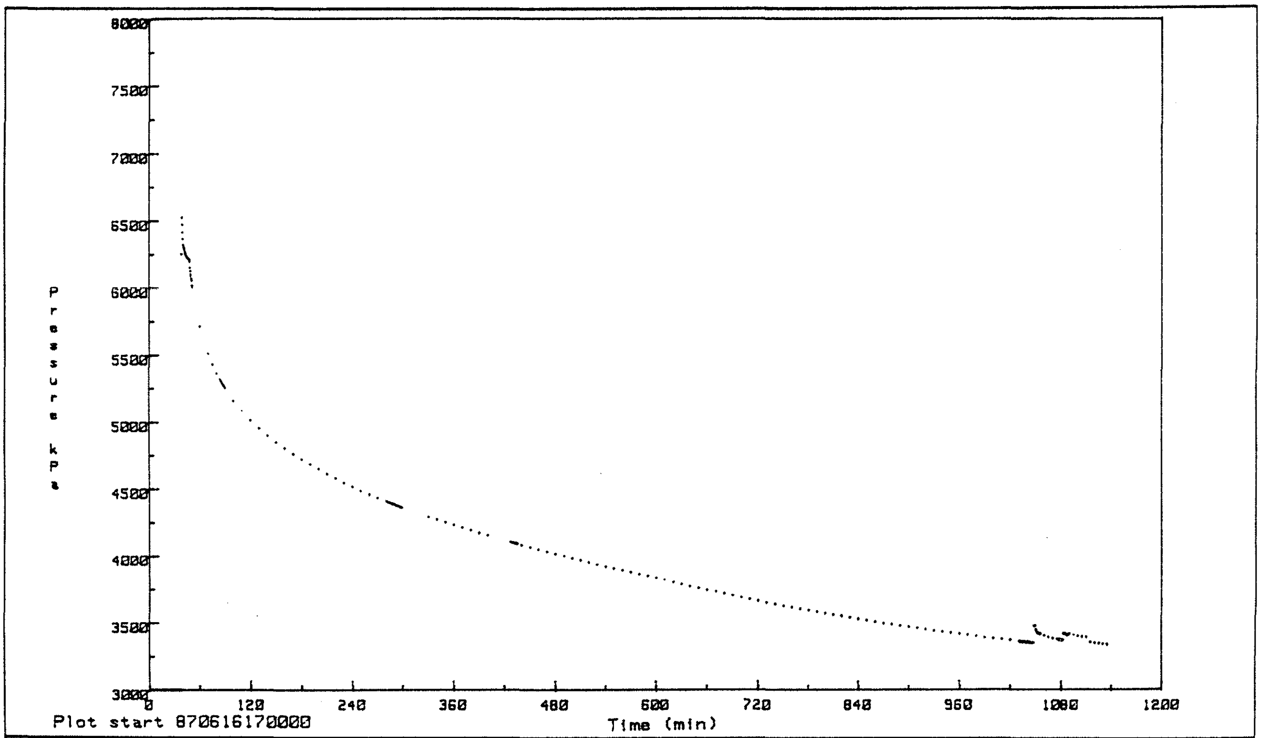
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.4

CASING TEST 1 ANNULUS AND BOTTOMHOLE PRESSURE RESPONSE



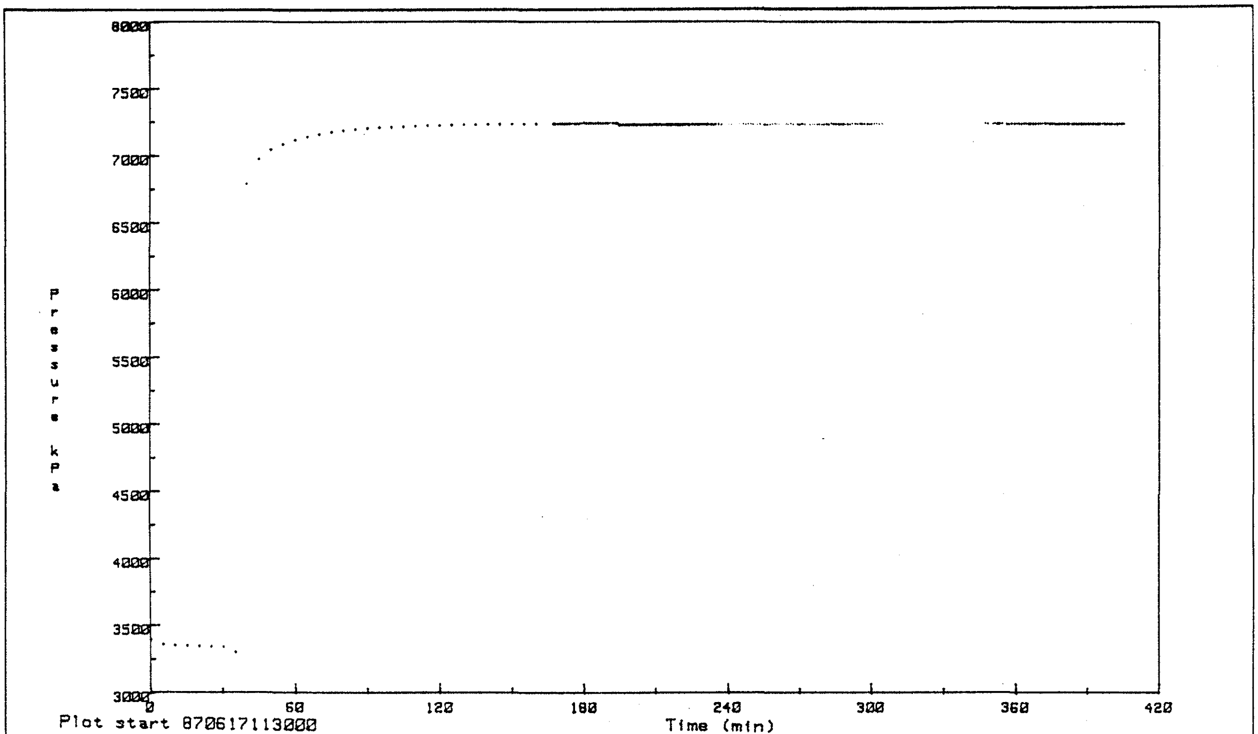
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	5.5

CASING TEST 2 CONFIGURATION



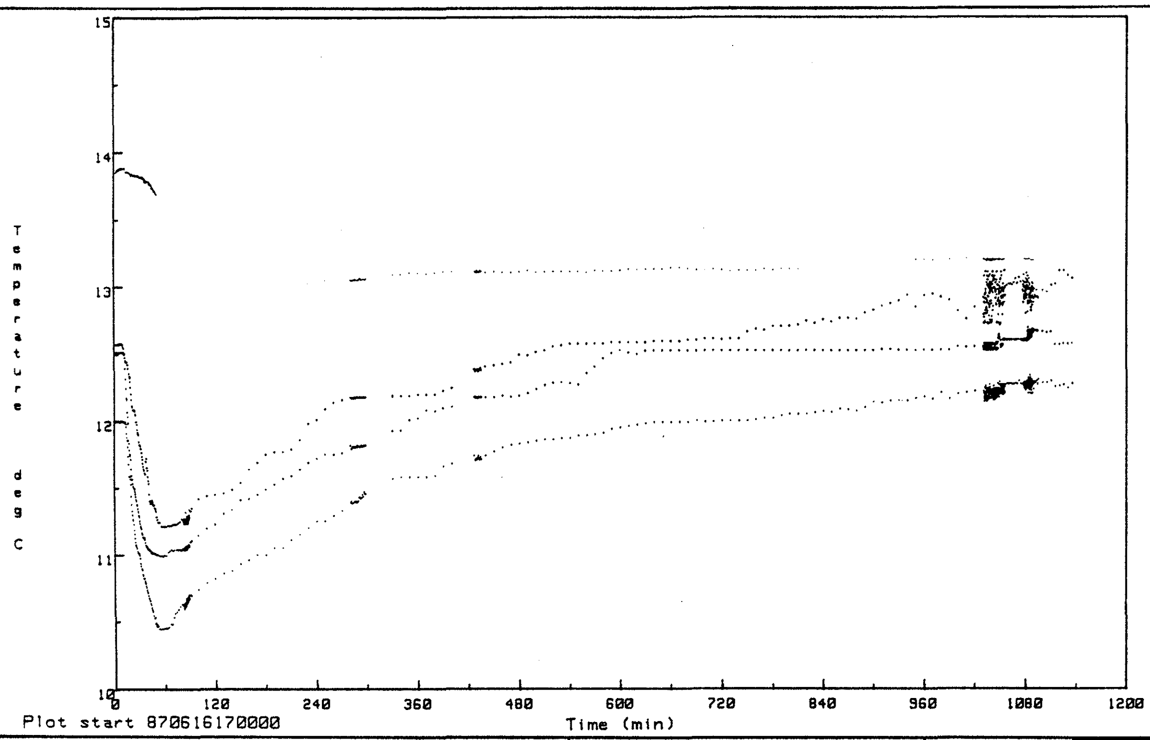
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.6

CASING TEST 2 PART 1 INFLATION PRESSURE RESPONSE



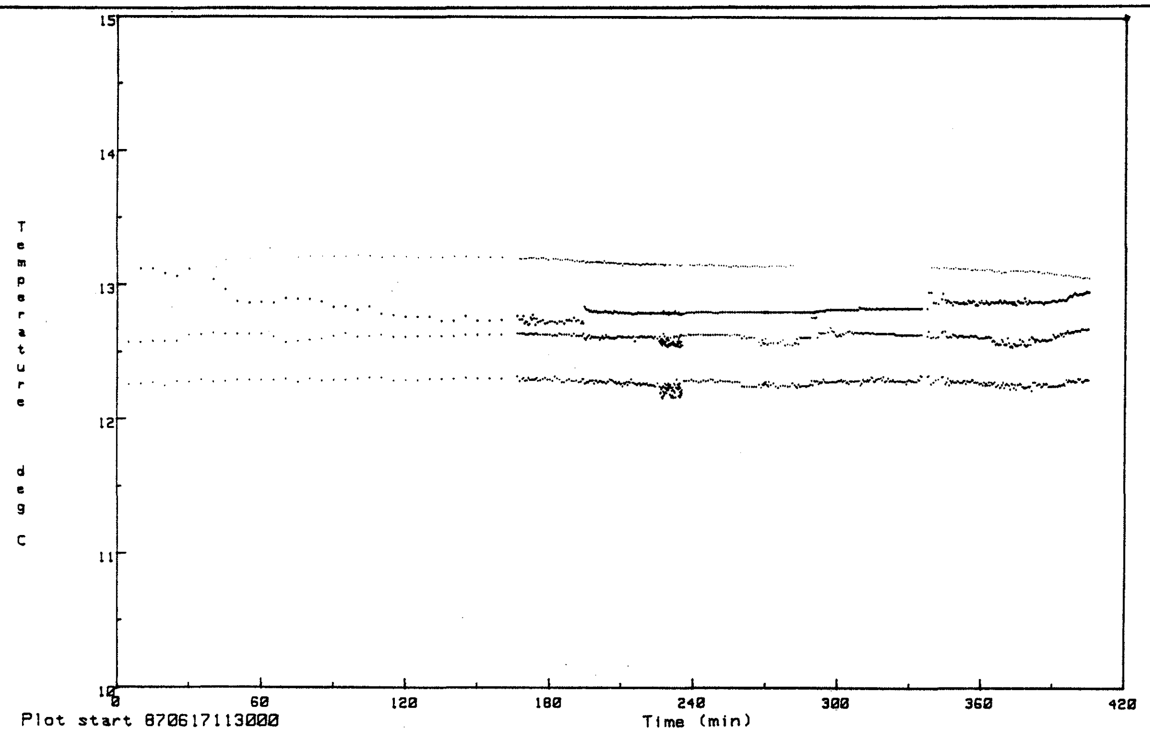
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.7

CASING TEST 2 PART 2 INFLATION PRESSURE RESPONSE



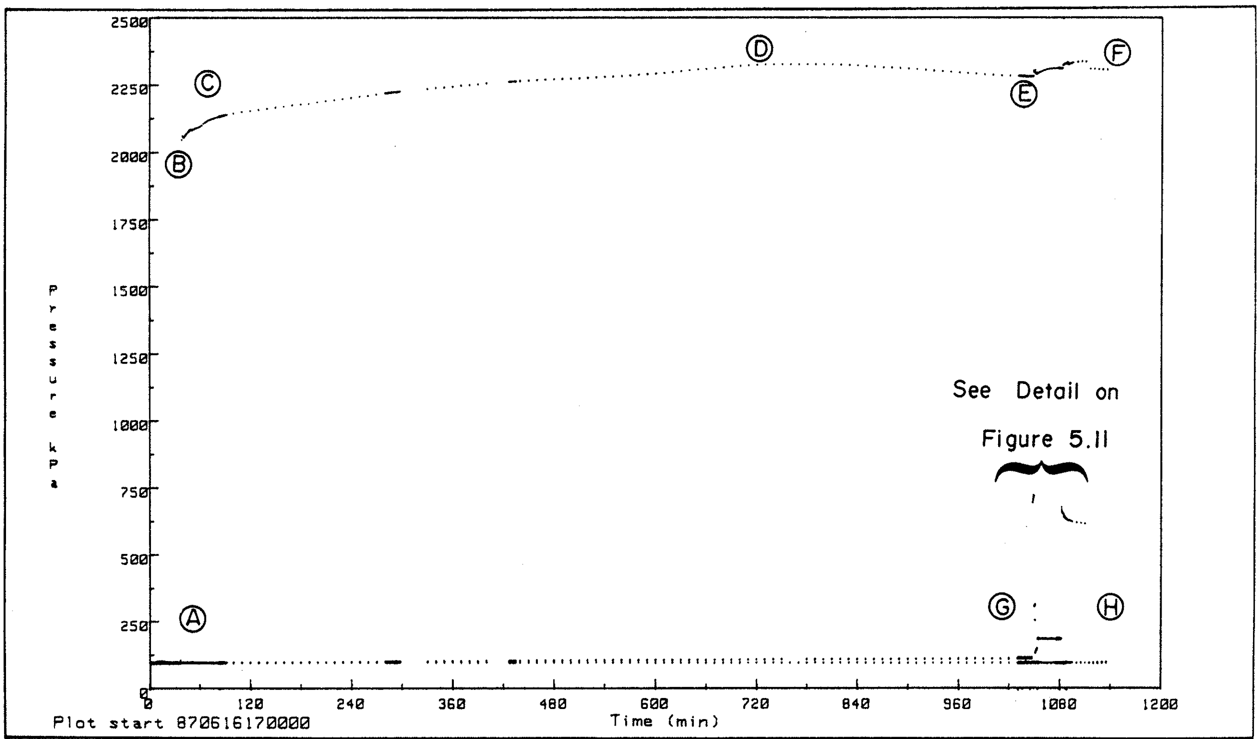
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.8

CASING TEST 2 PART 1 TEMPERATURE RESPONSE



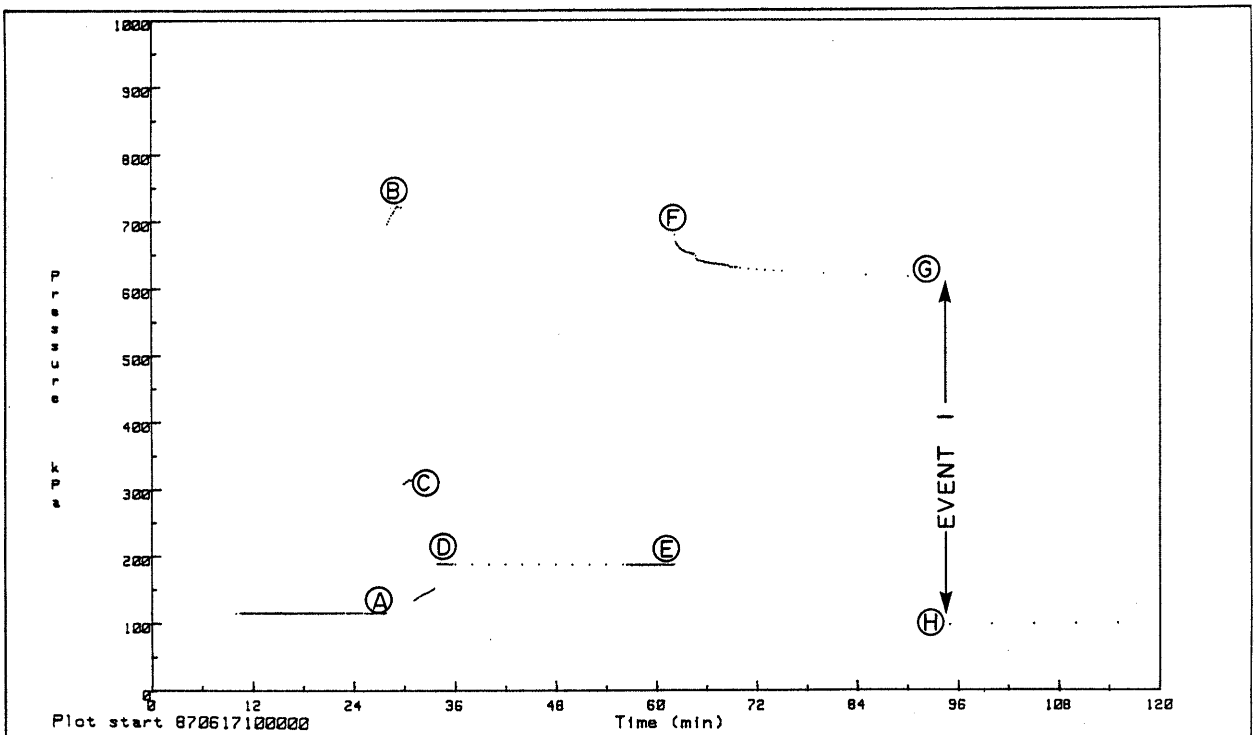
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 5.9

CASING TEST 2 PART 2 TEMPERATURE RESPONSE



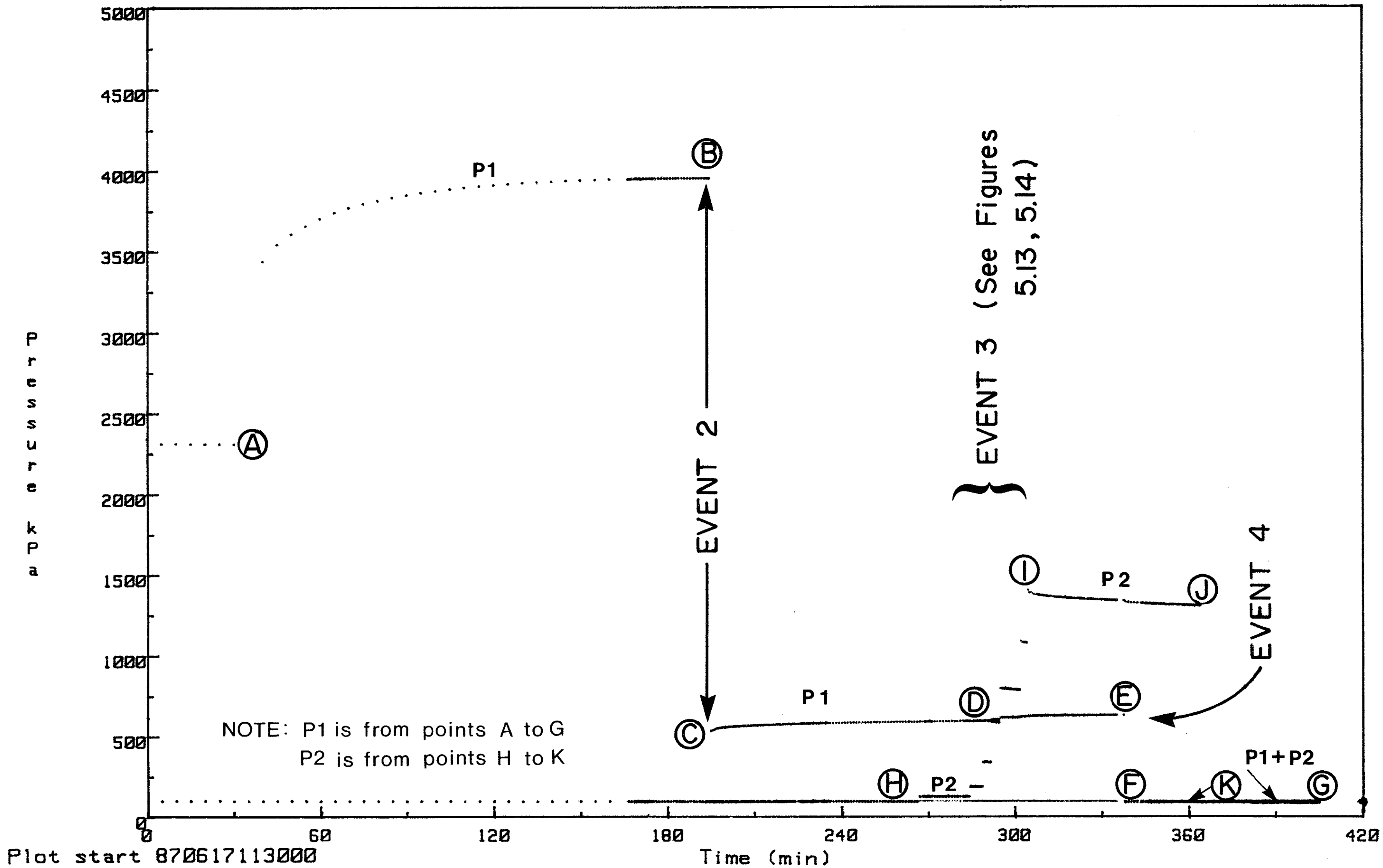
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 5.10

CASING TEST 2 PART 1 INTERVAL PRESSURE RESPONSES



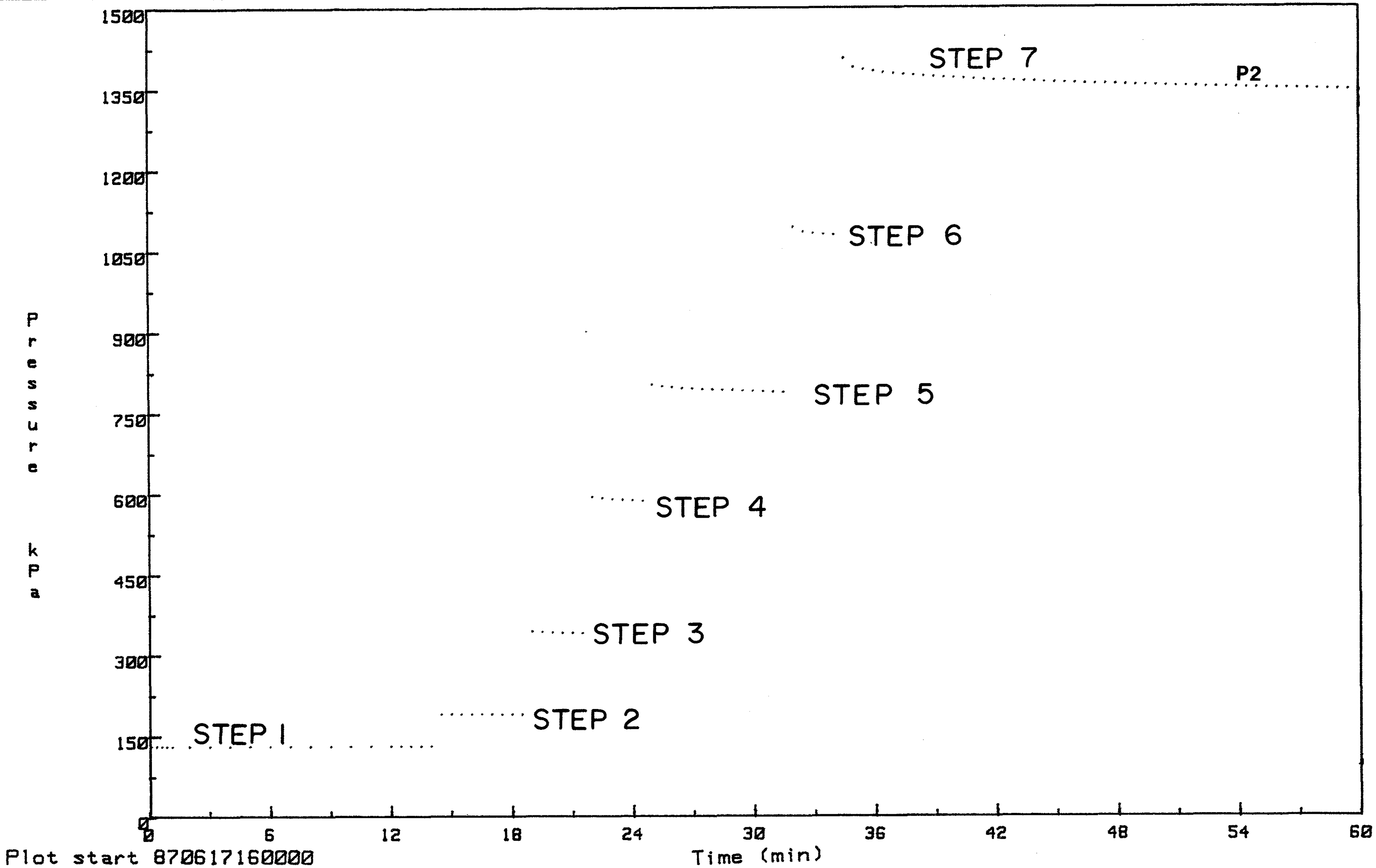
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 5.11

DETAIL OF CASING TEST 2 PART 1 PRESSURE RESPONSES



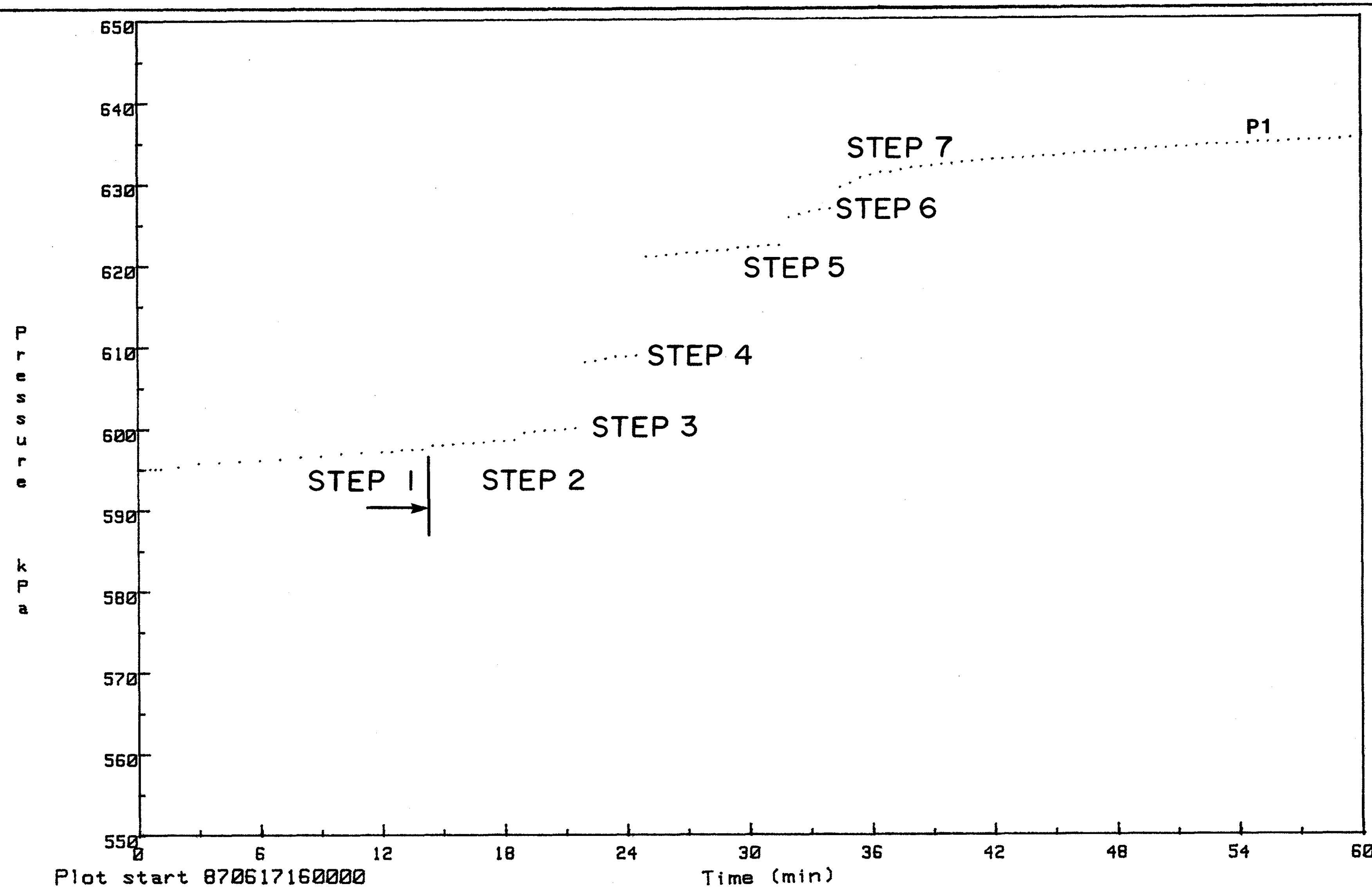
NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	5.12

CASING TEST 2 PART 2, EVENT INTERVAL PRESSURE RESPONSES



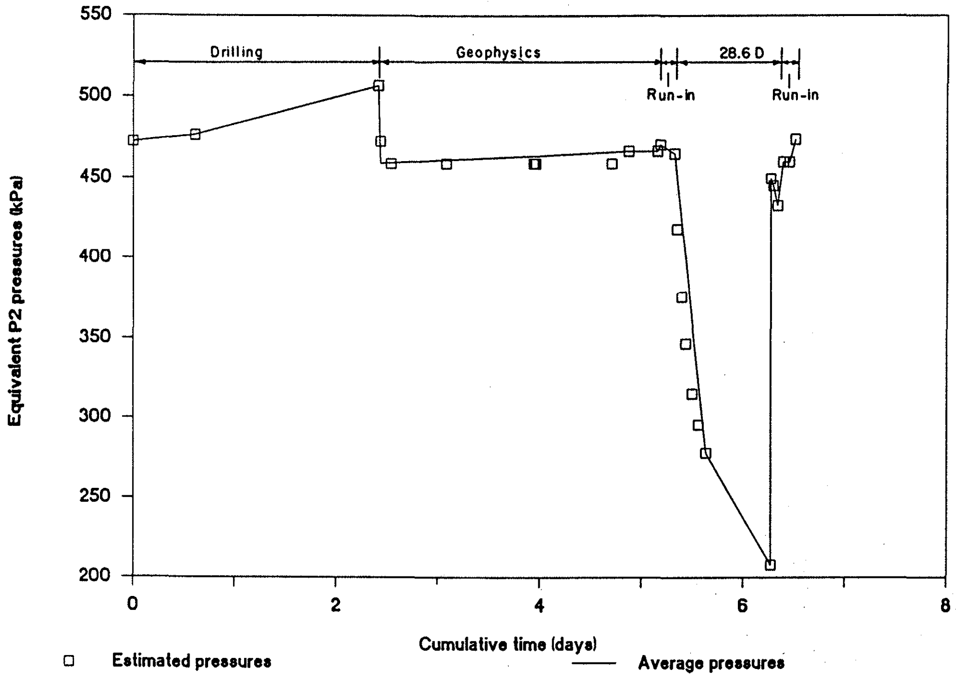
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	5.13

INTERVAL PRESSURE RESPONSE DURING INJECTION STEPS



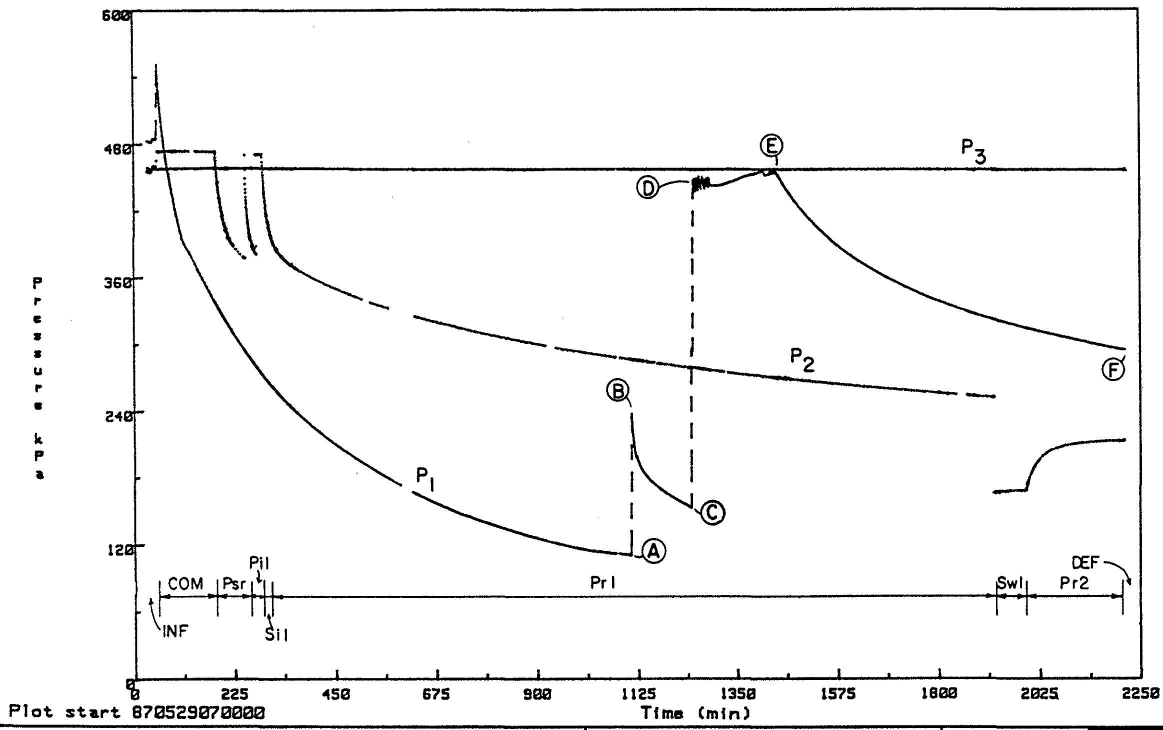
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	5.14

BELOW PACKER PRESSURE RESPONSE DURING INJECTION STEPS



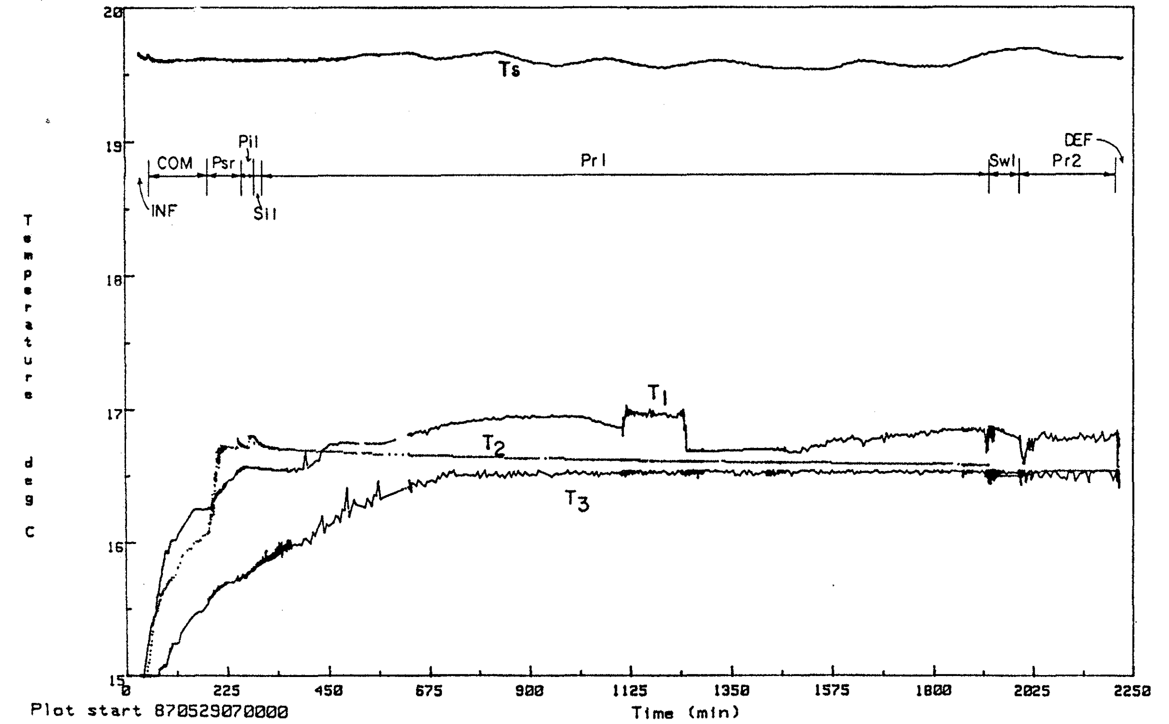
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.1

ESTIMATED BOREHOLE HISTORY PRESSURES HVB/48.6D



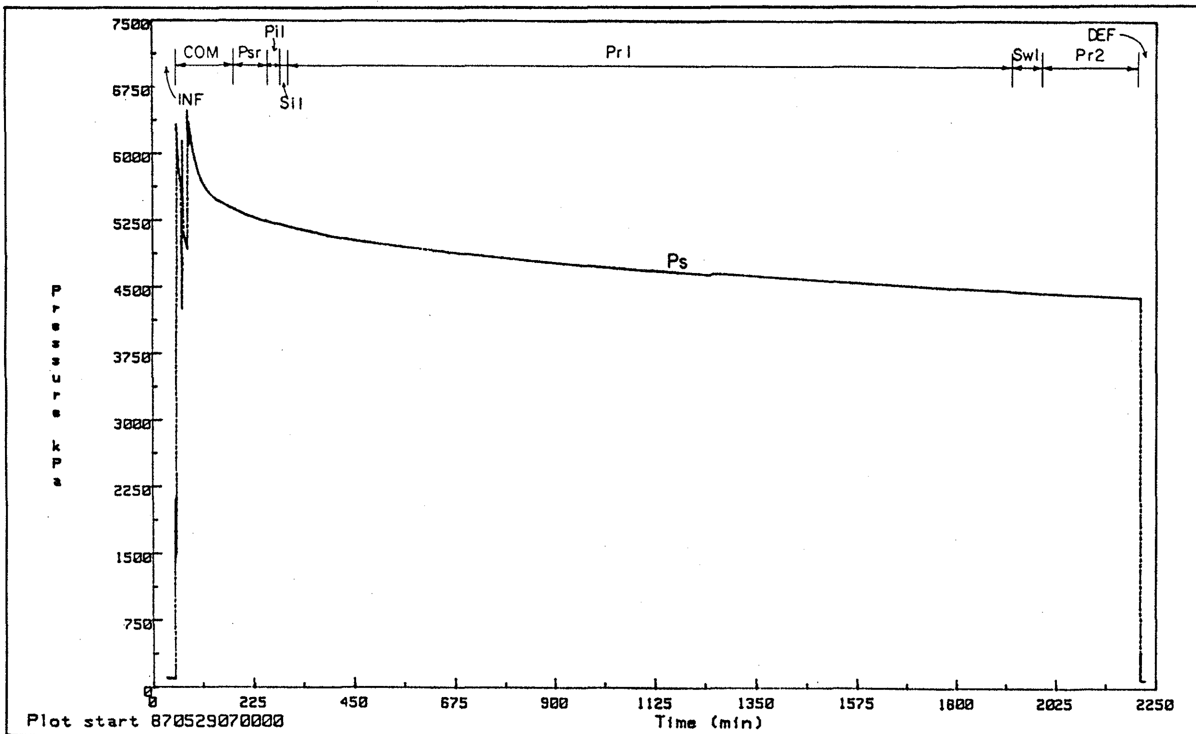
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.2

PRESSURES DURING TESTING HVB/48.6D



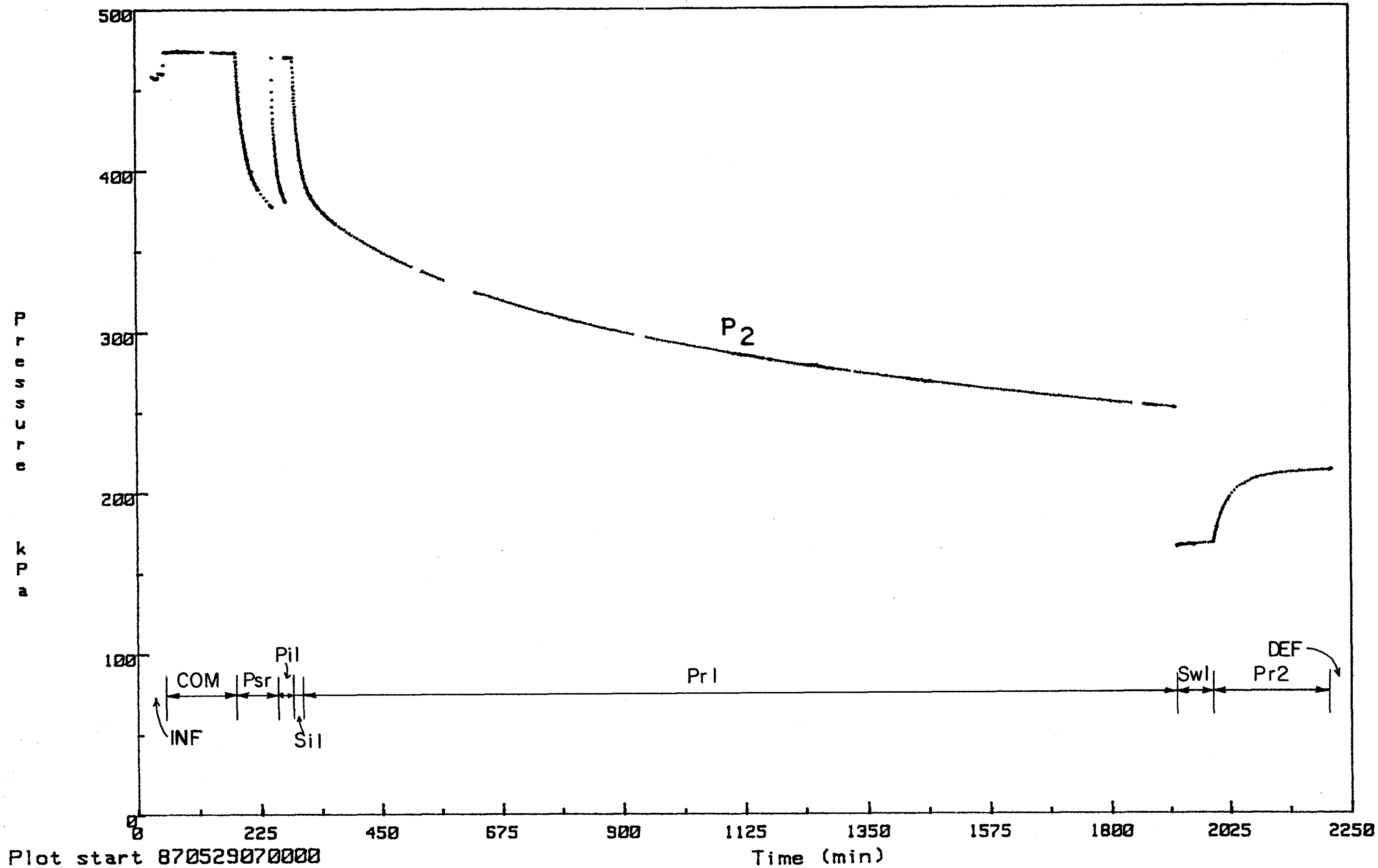
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.3

TEMPERATURES DURING TESTING HVB/48.6D



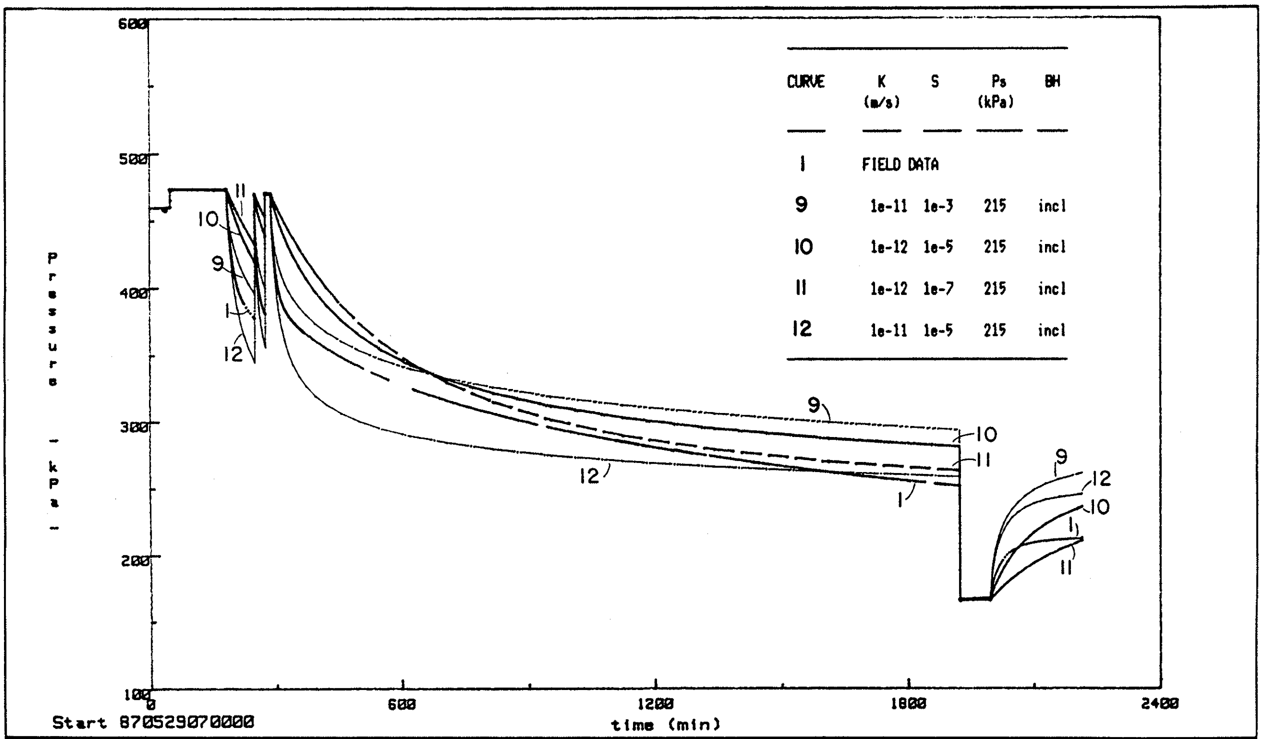
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.4

PACKER INFLATION LINE PRESSURE DURING TESTING HVB/48.6D



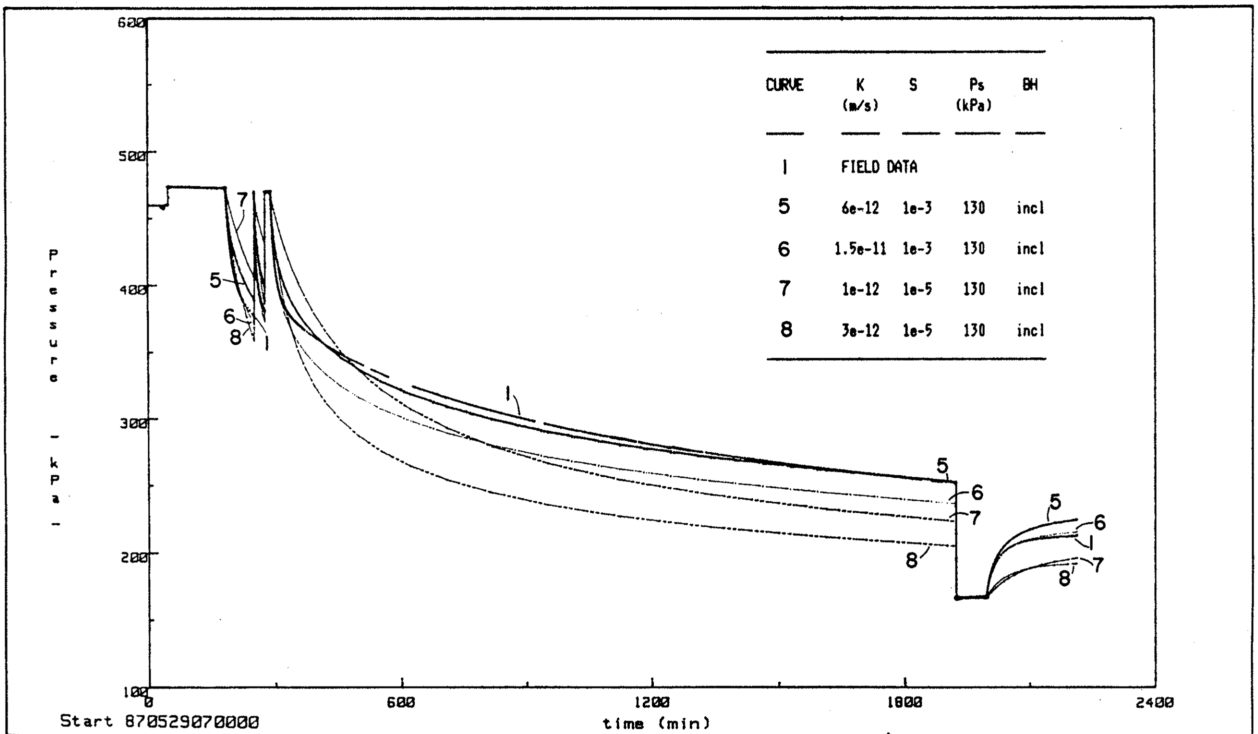
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.5

INTERVAL PRESSURE DURING TESTING HVB/48.6D



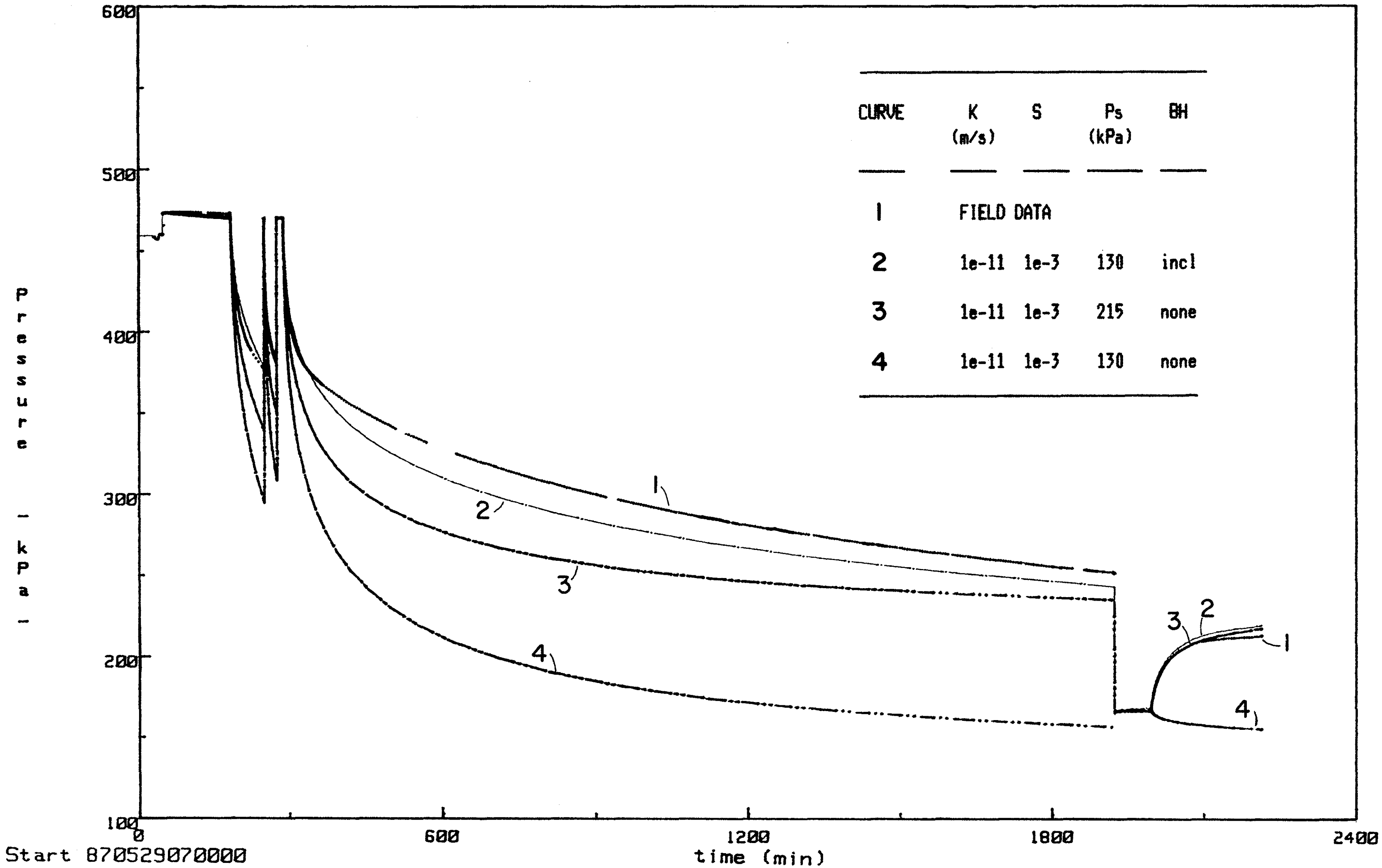
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.6

HYDRAULIC CONDUCTIVITY AND STORATIVITY SENSITIVITY AT A STATIC PRESSURE OF 215 kPa HVB/48.6D



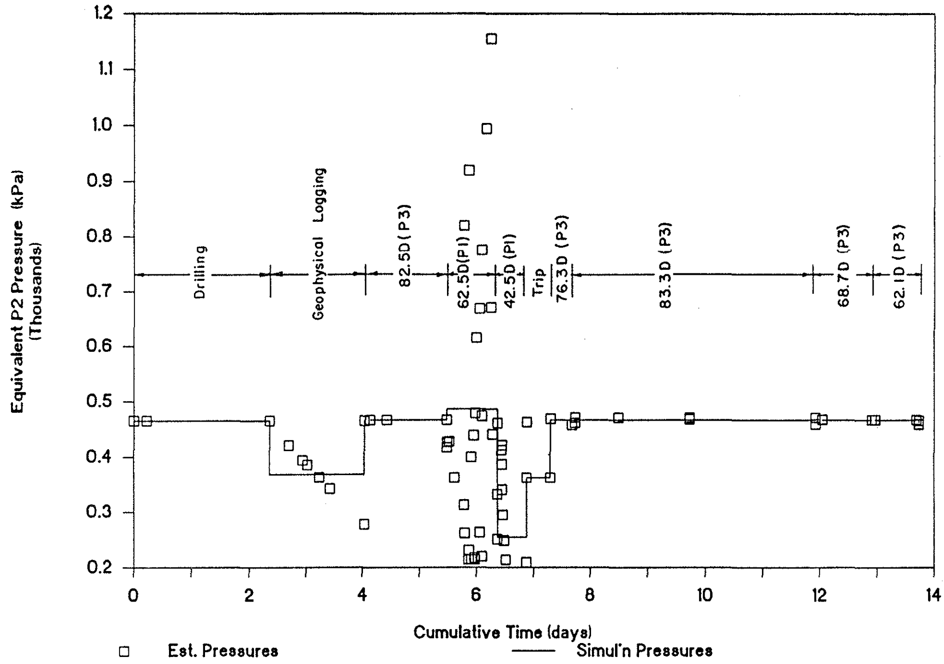
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.7

HYDRAULIC CONDUCTIVITY AND STORATIVITY SENSITIVITY AT A STATIC PRESSURE OF 130 kPa HVB/48.6D



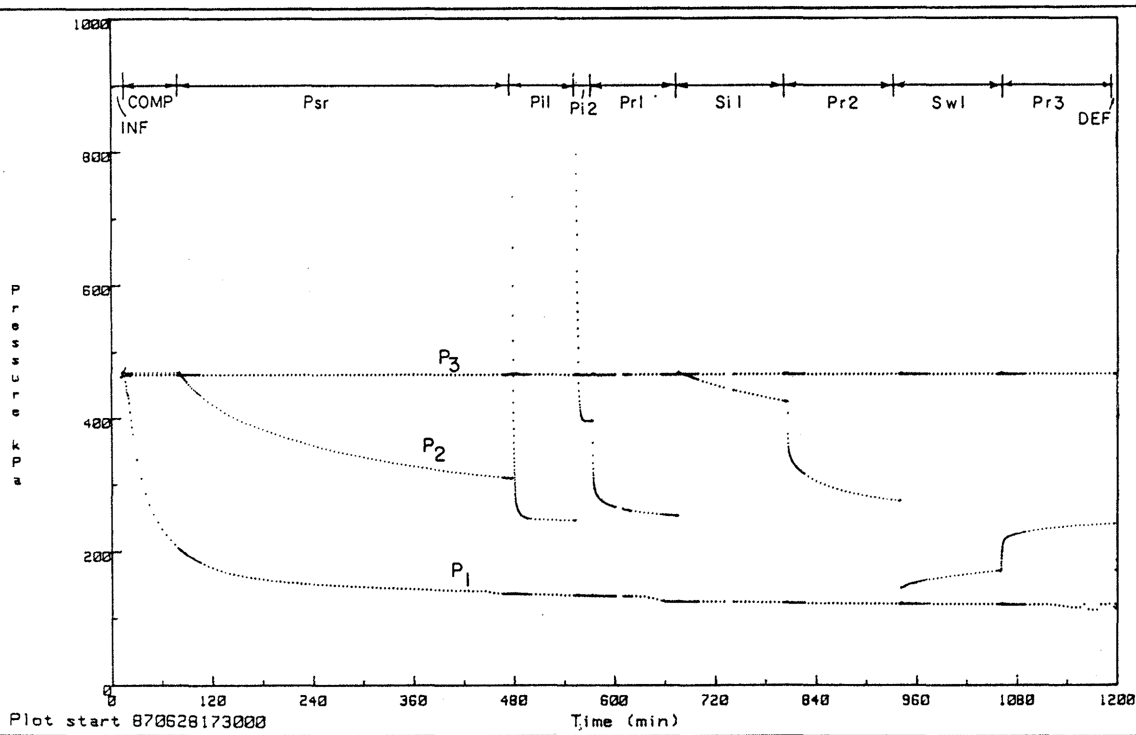
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.8

BOREHOLE HISTORY SENSITIVITY HVB/48.6D



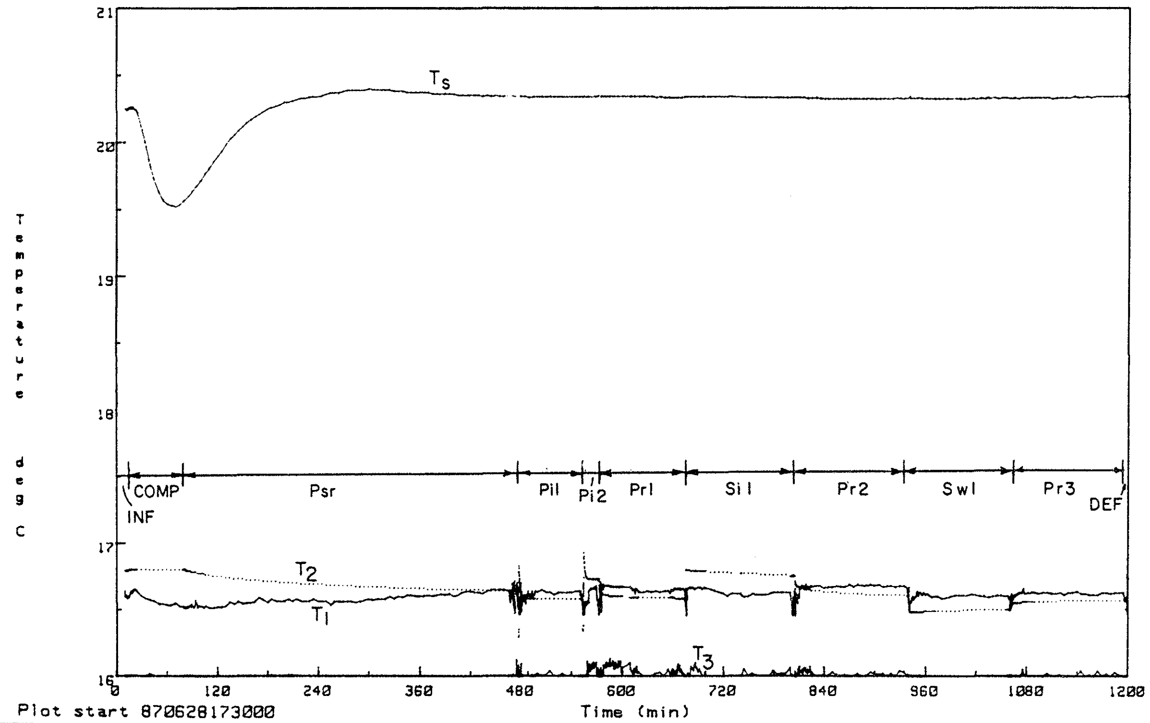
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 6.9

ESTIMATED BOREHOLE HISTORY PRESSURES HGB/55.5D1



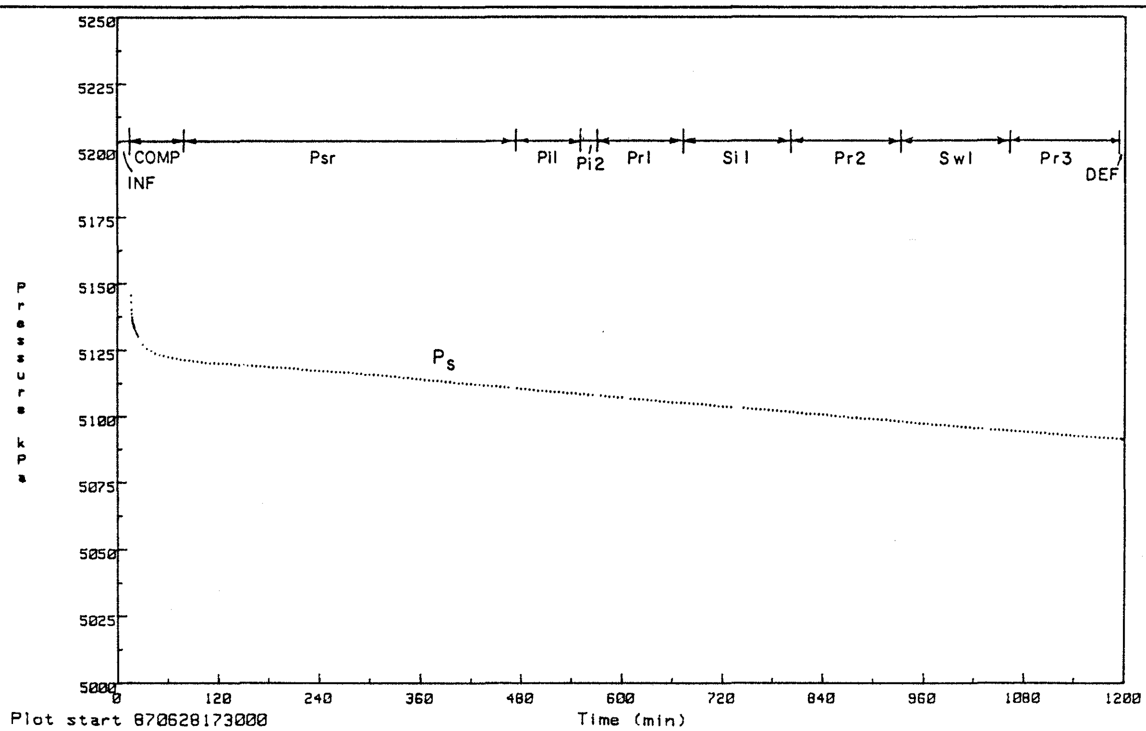
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 6.10

PRESSURES DURING TESTING HGB/55.5D1



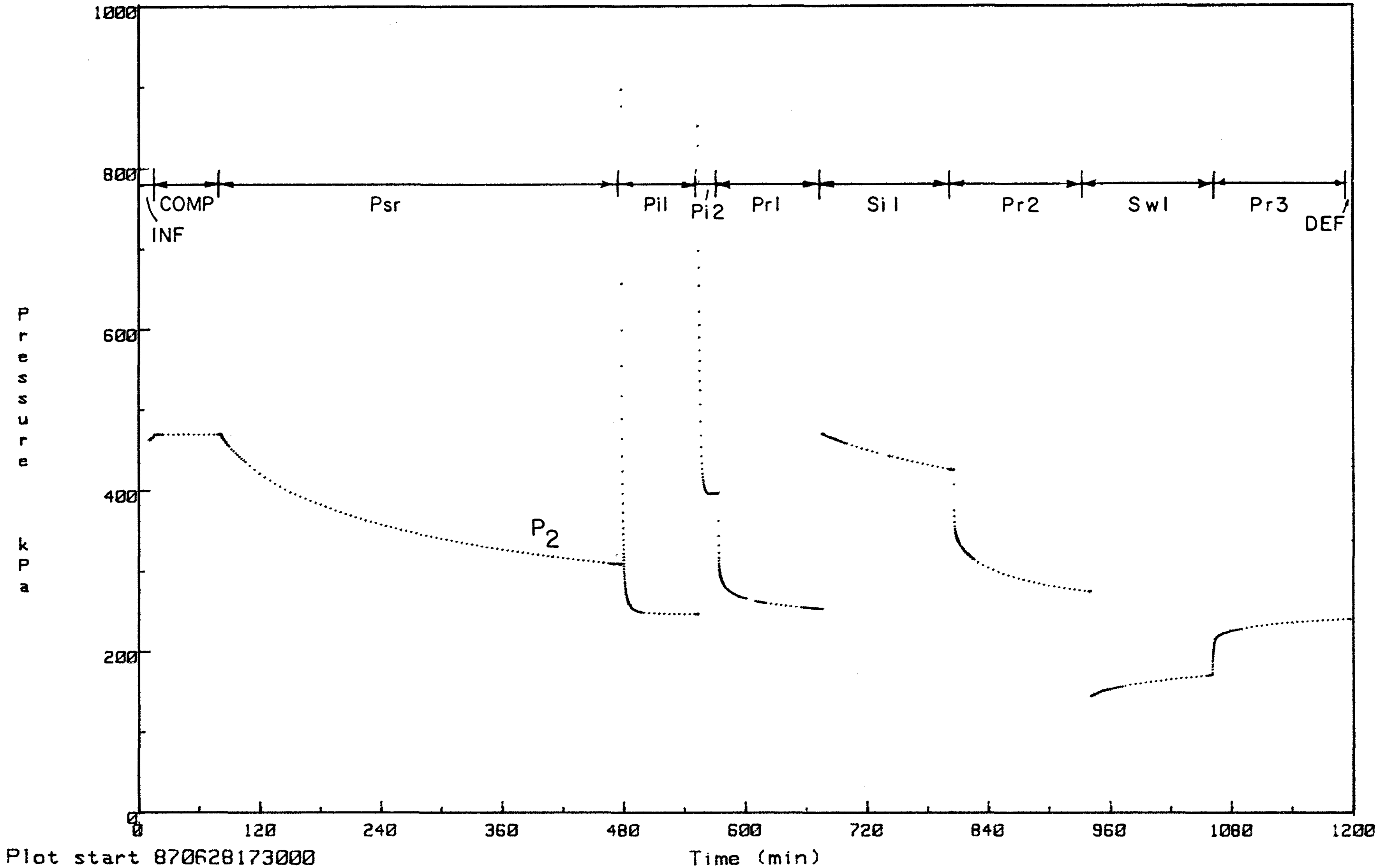
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 6.11

TEMPERATURES DURING TESTING HGB/55.5D1



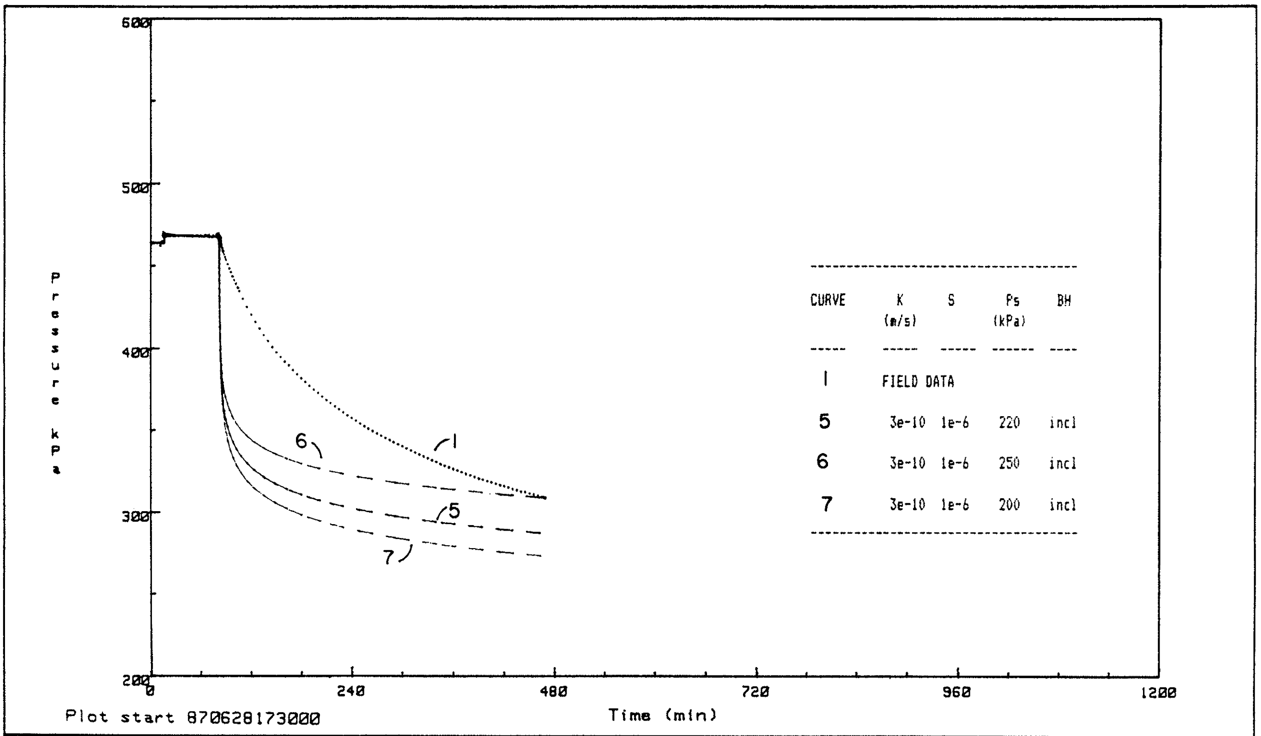
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 6.12

PACKER INFLATION LINE PRESSURE DURING TESTING HGB/55.5D1



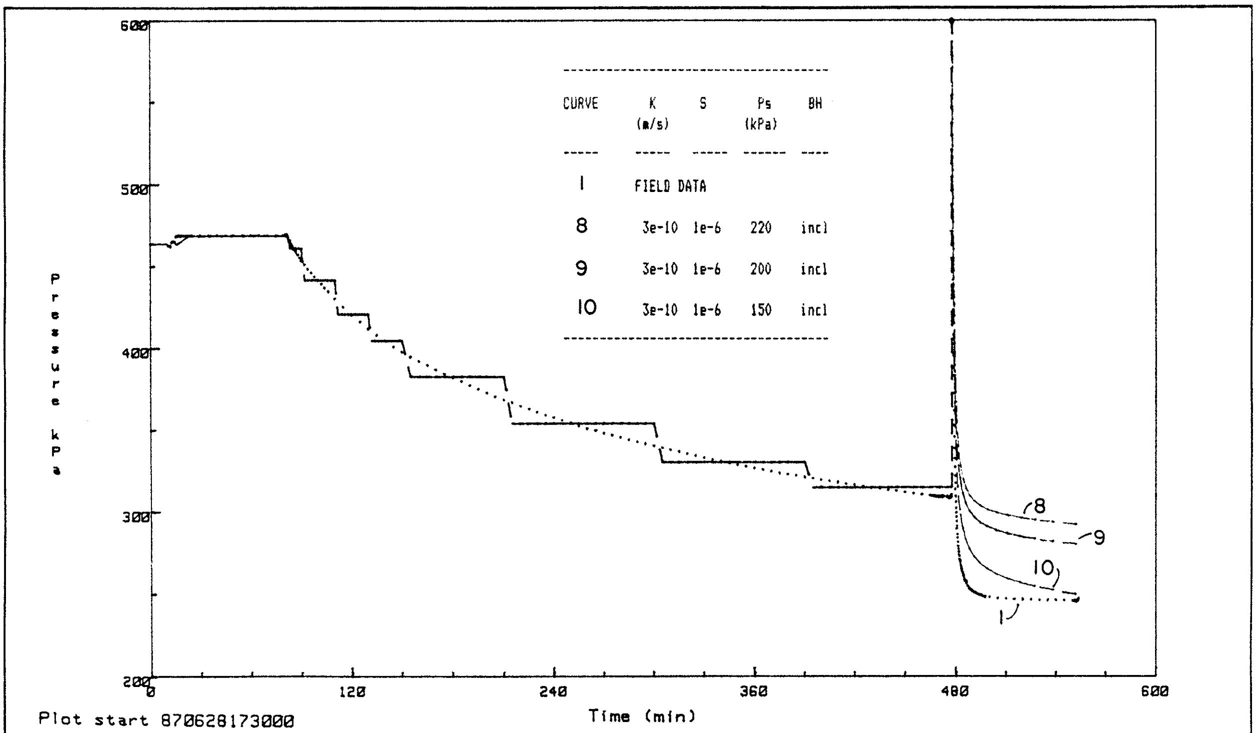
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.13

INTERVAL PRESSURES DURING TESTING HGB/55.5D1



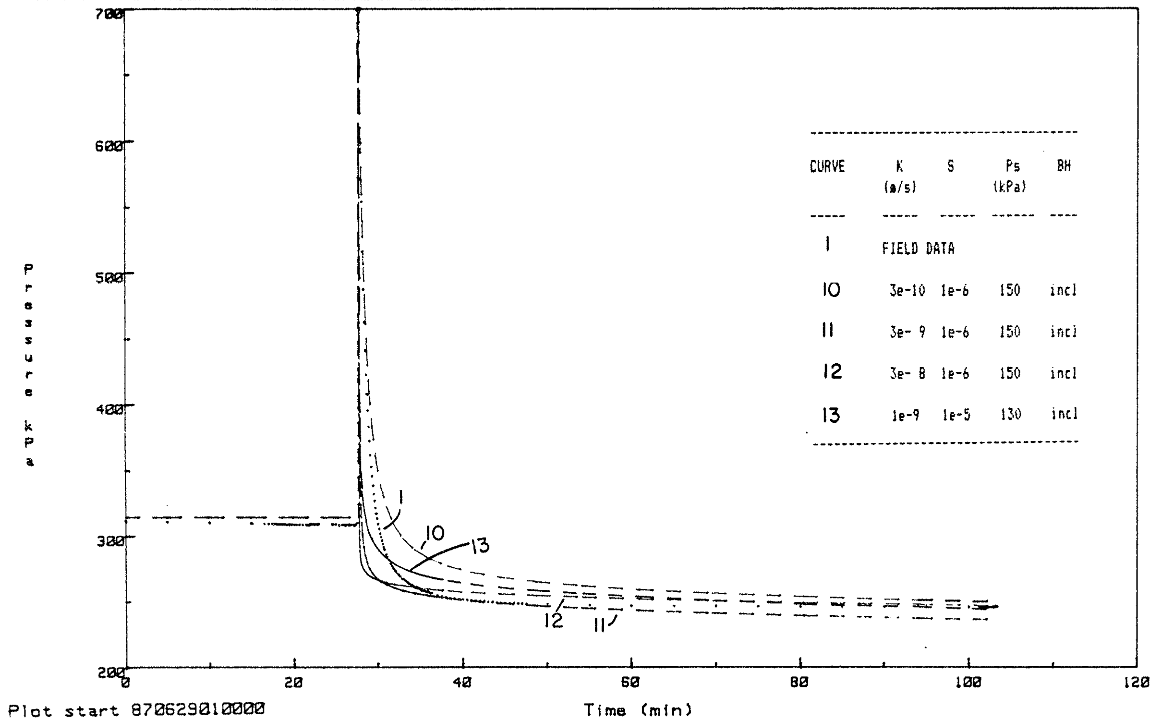
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.14

INITIAL EVENTS SENSITIVITY HGB/55.5D1



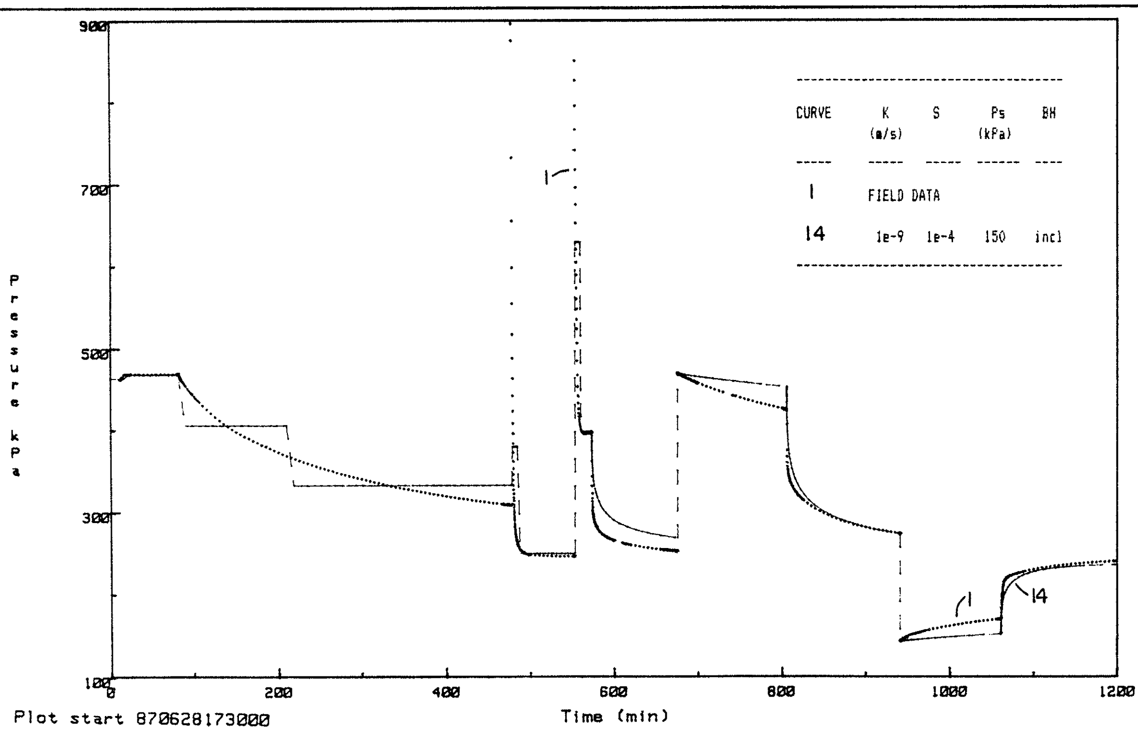
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.15

CONSTANT PRESSURE DISCRETIZATION OF FIRST TWO EVENTS HGB/55.5D1



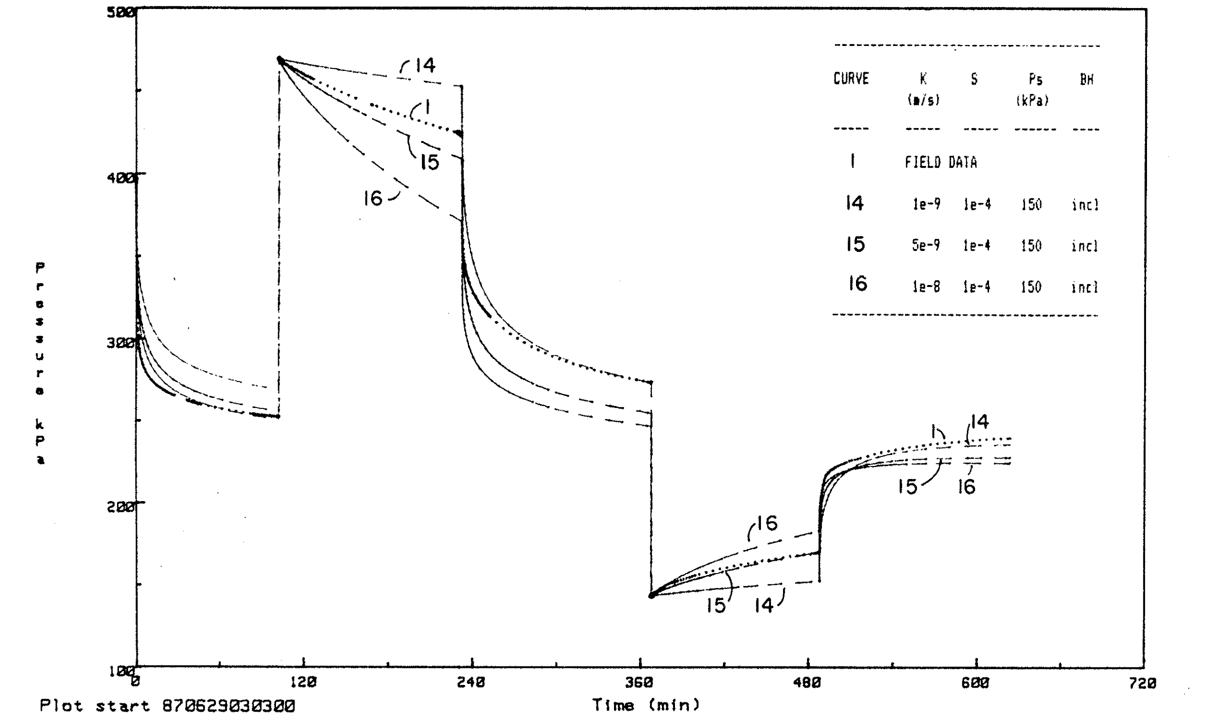
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.16

EVENT Pi1 SENSITIVITY ANALYSIS HGB 55.5D1



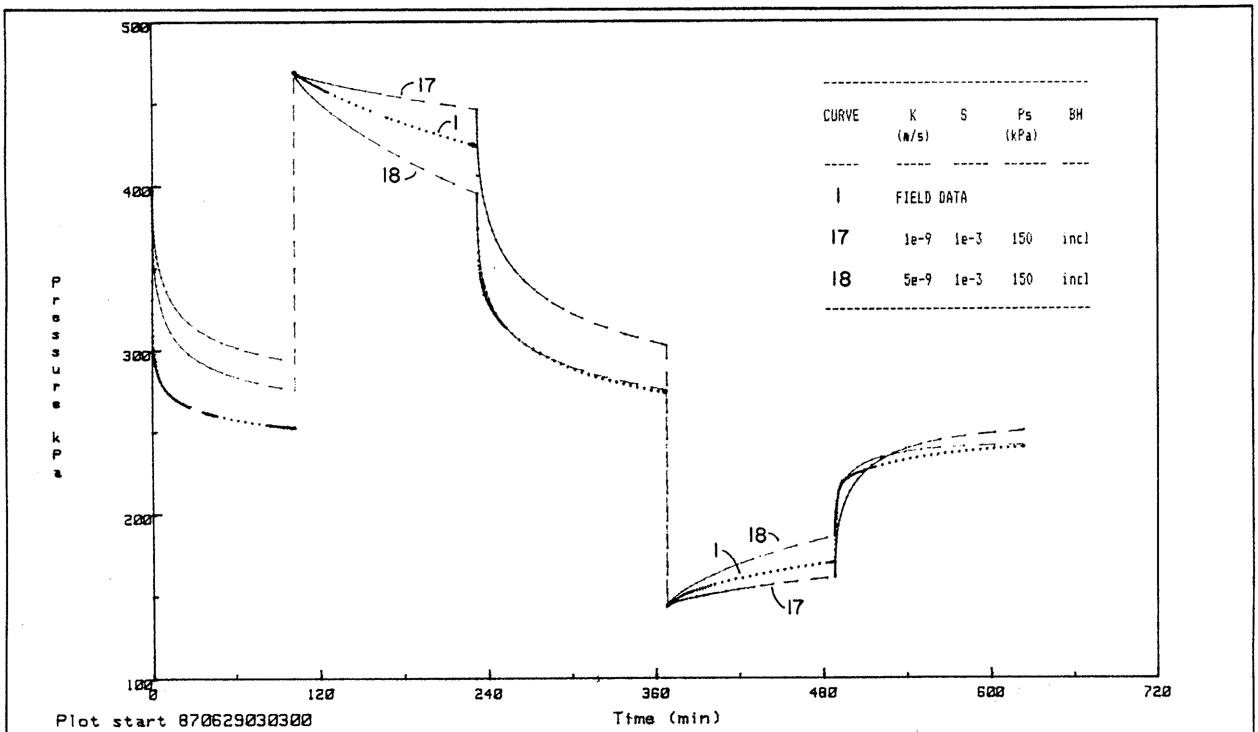
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.17

EVENT PRESSURE SETUP FOR SENSITIVITY ANALYSIS OF FINAL FOUR EVENTS HGB/55.5D



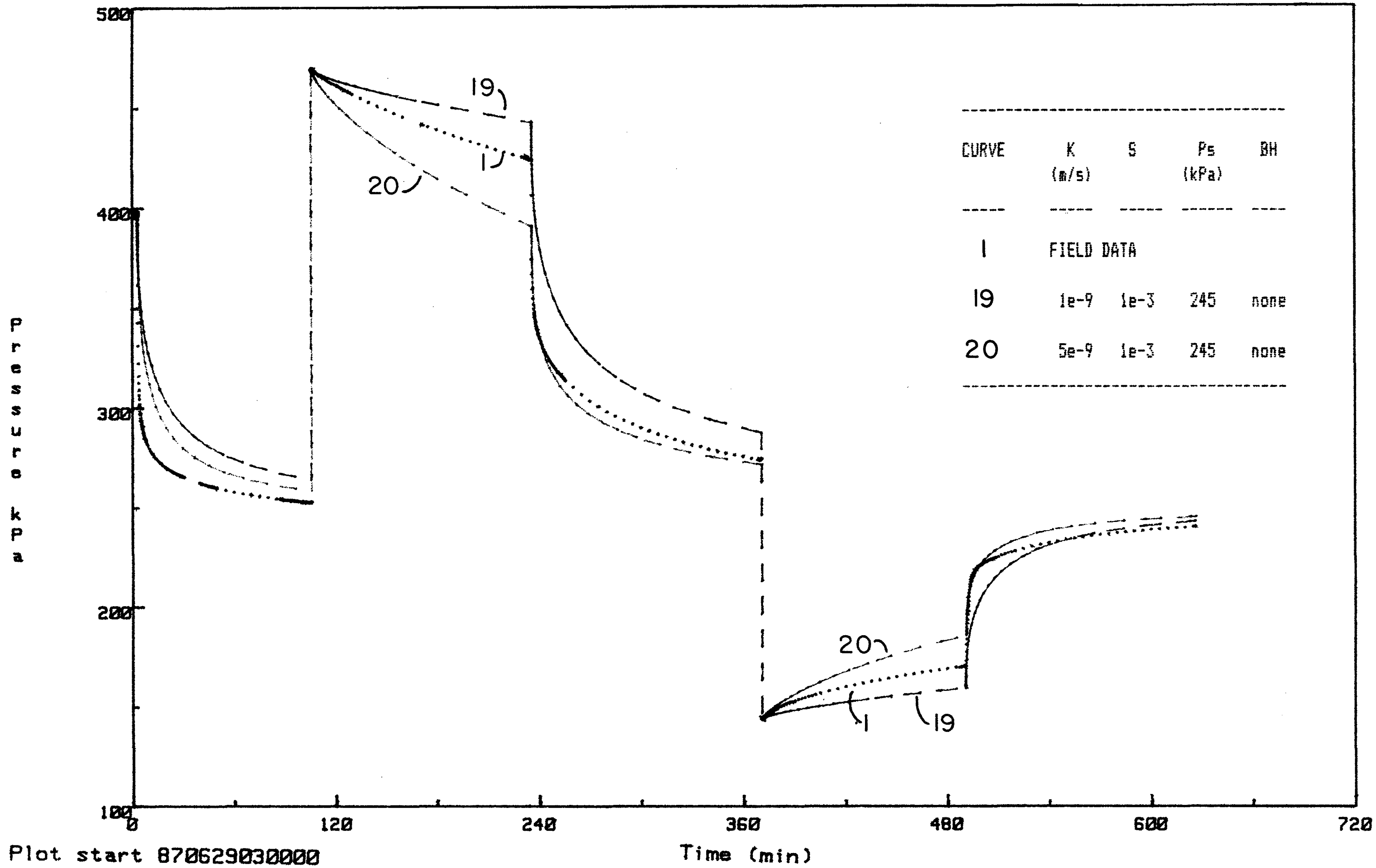
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.18

FINAL FOUR EVENT SENSITIVITY ANALYSIS AT A STORATIVITY OF $1e^{-4}$ HGB/55.5D1



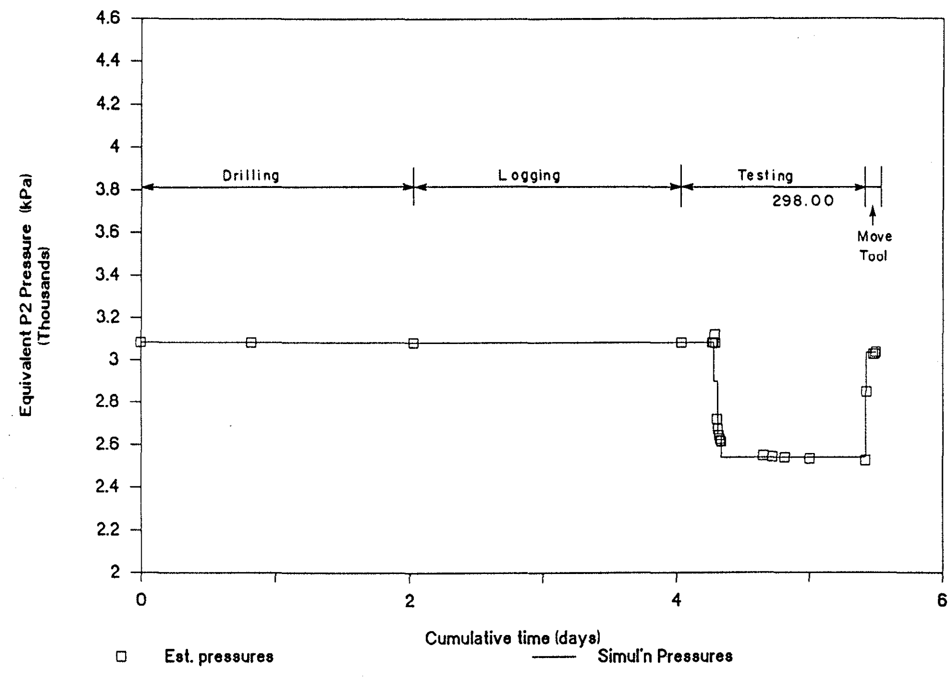
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.19

FINAL FOUR EVENT SENSITIVITY ANALYSIS AT A STORATIVITY OF **1e-3** HGB/55.5D1



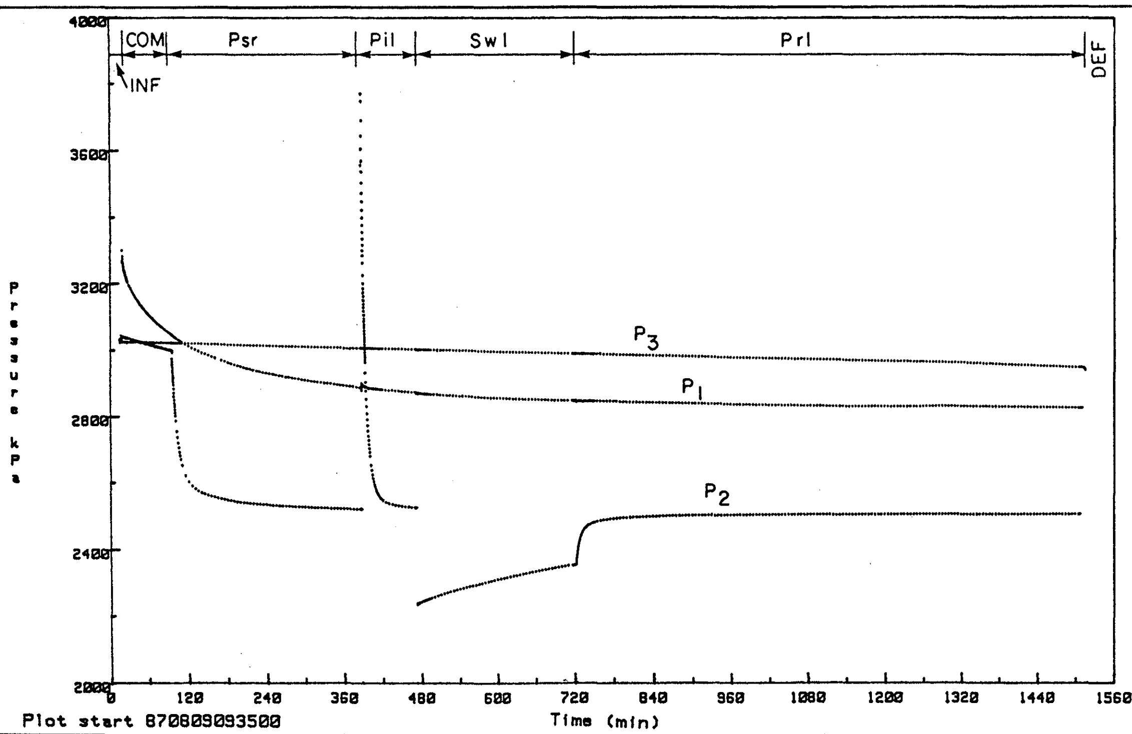
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.20

FINAL FOUR EVENT SENSITIVITY ANALYSIS WITHOUT BOREHOLE HISTORY HGB/55.5D1



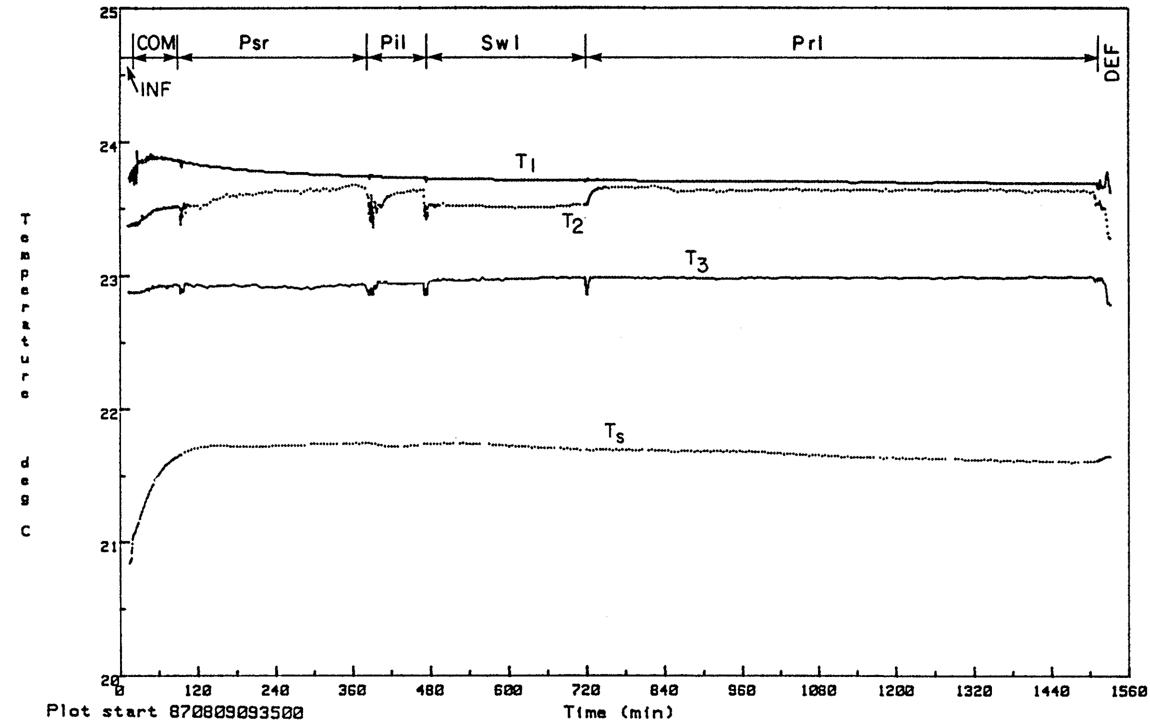
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.21

ESTIMATED BOREHOLE HISTORY PRESSURES SA/311.OD



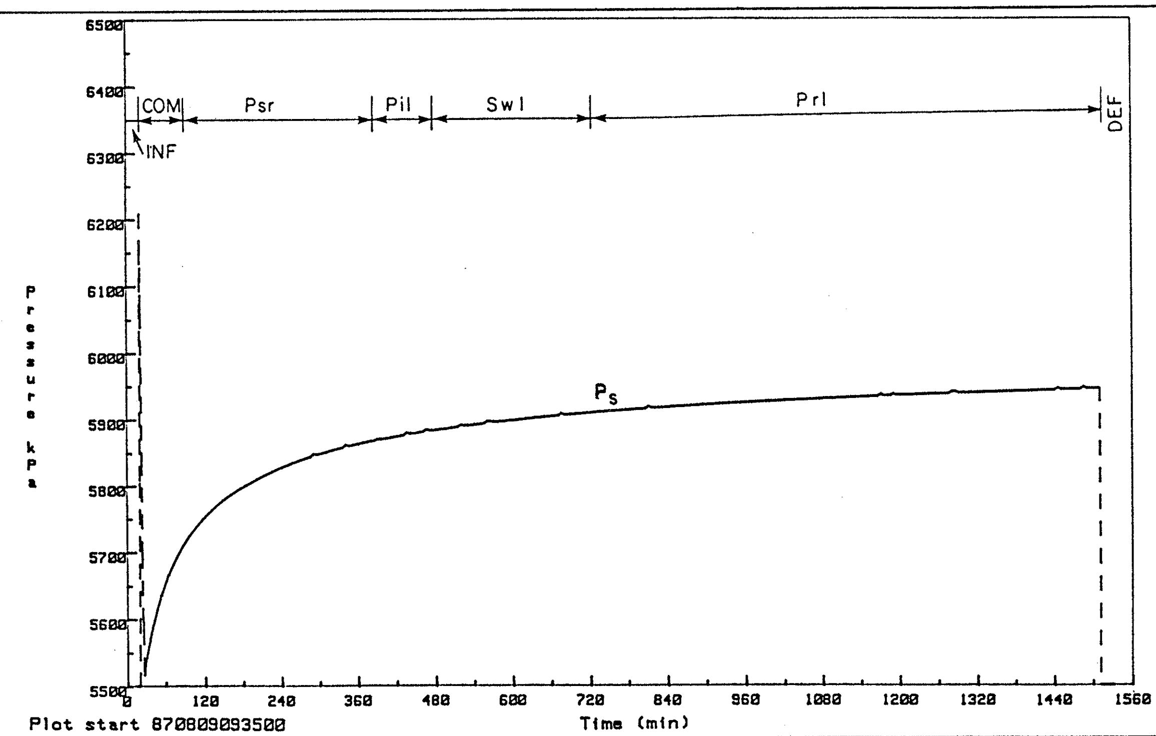
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.22

PRESSURES DURING TESTING SA/311.OD



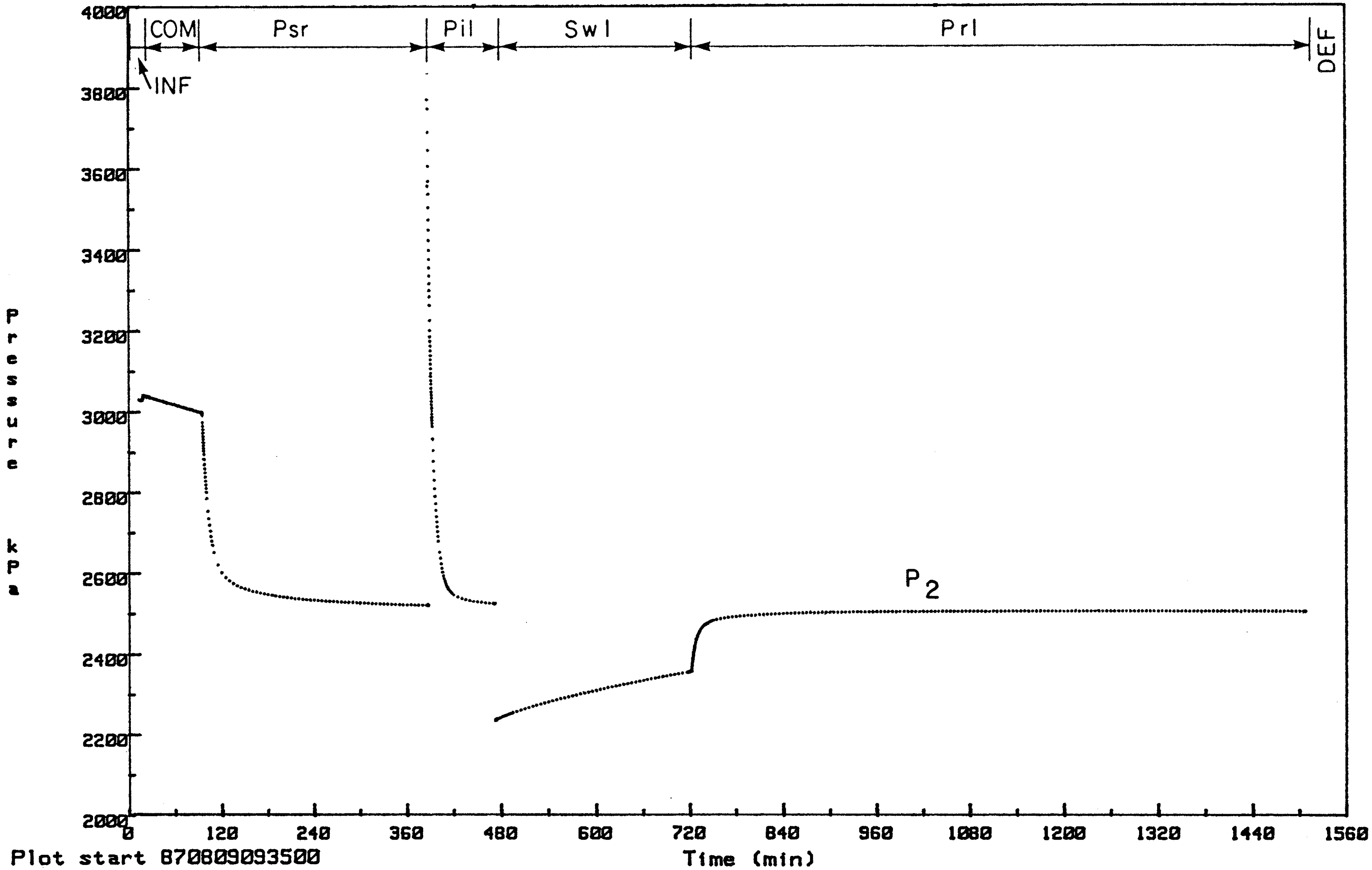
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 6.23

TEMPERATURES DURING TESTING SA/311.OD



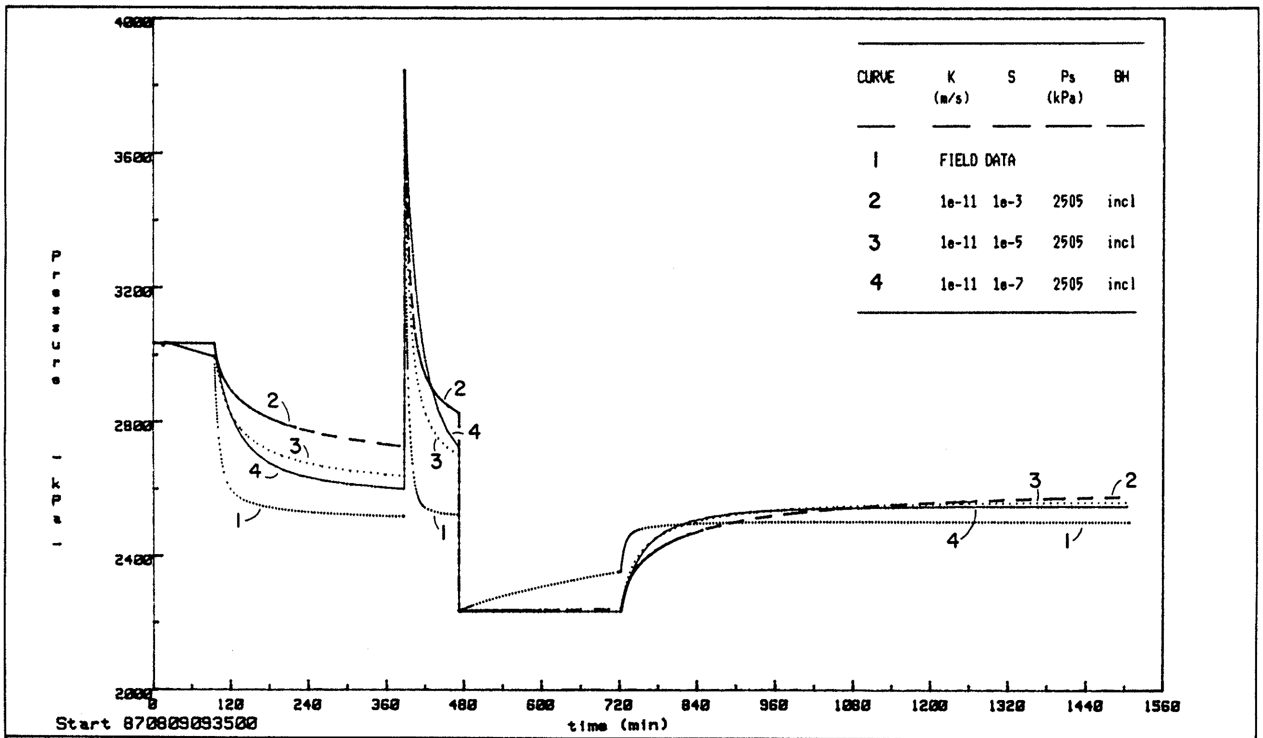
NAGRA / GLAG NTB: 88-03 OBERBAUENSTOCK DAT.: APR. 88 6.24

PACKER INFLATION LINE PRESSURE DURING TESTING SA/311.OD



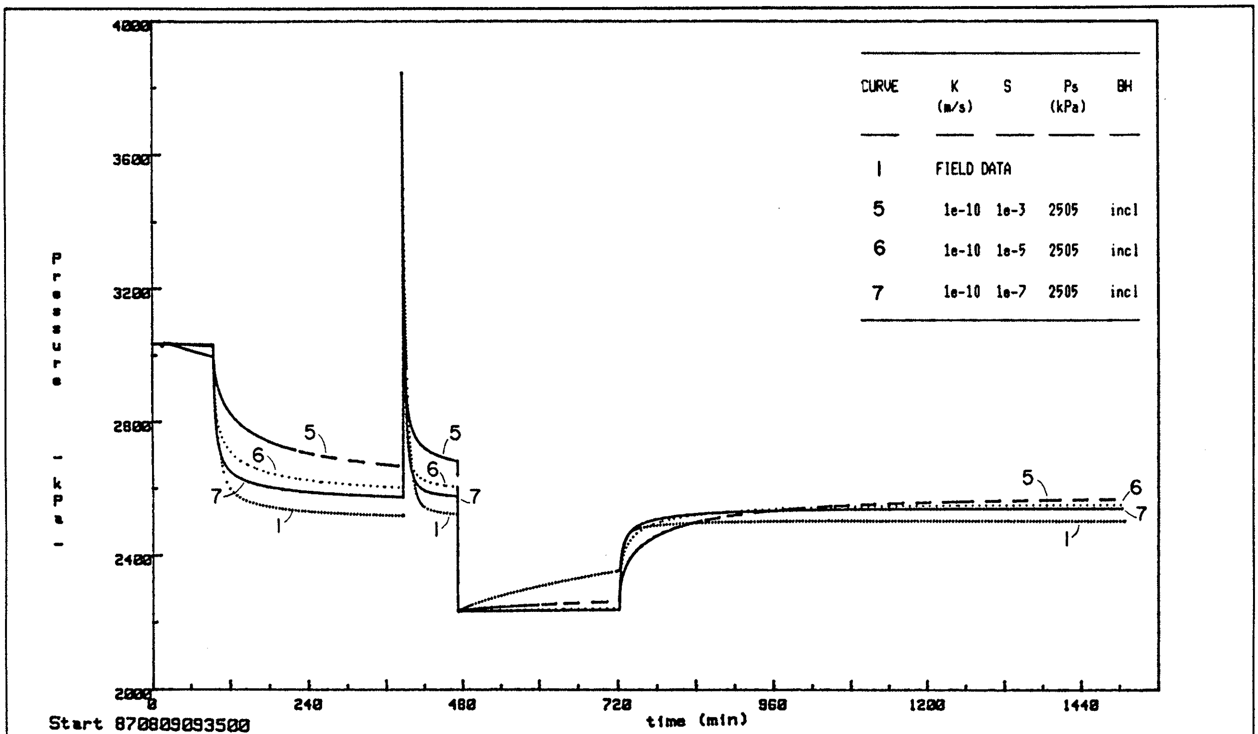
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.25

INTERVAL PRESSURE DURING TESTING SA/311.OD



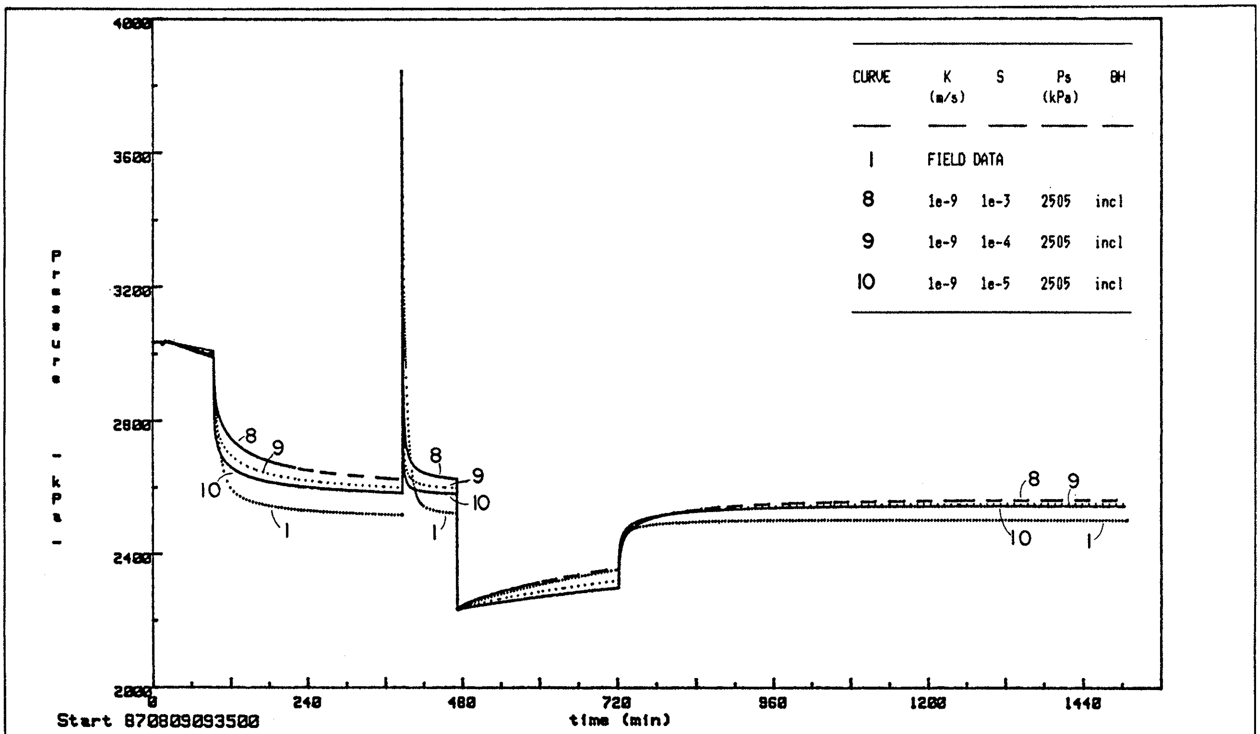
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.26(a)

SENSITIVITY ANALYSES AT A HYDRAULIC CONDUCTIVY OF 1e-11 m/s SA/311.0D



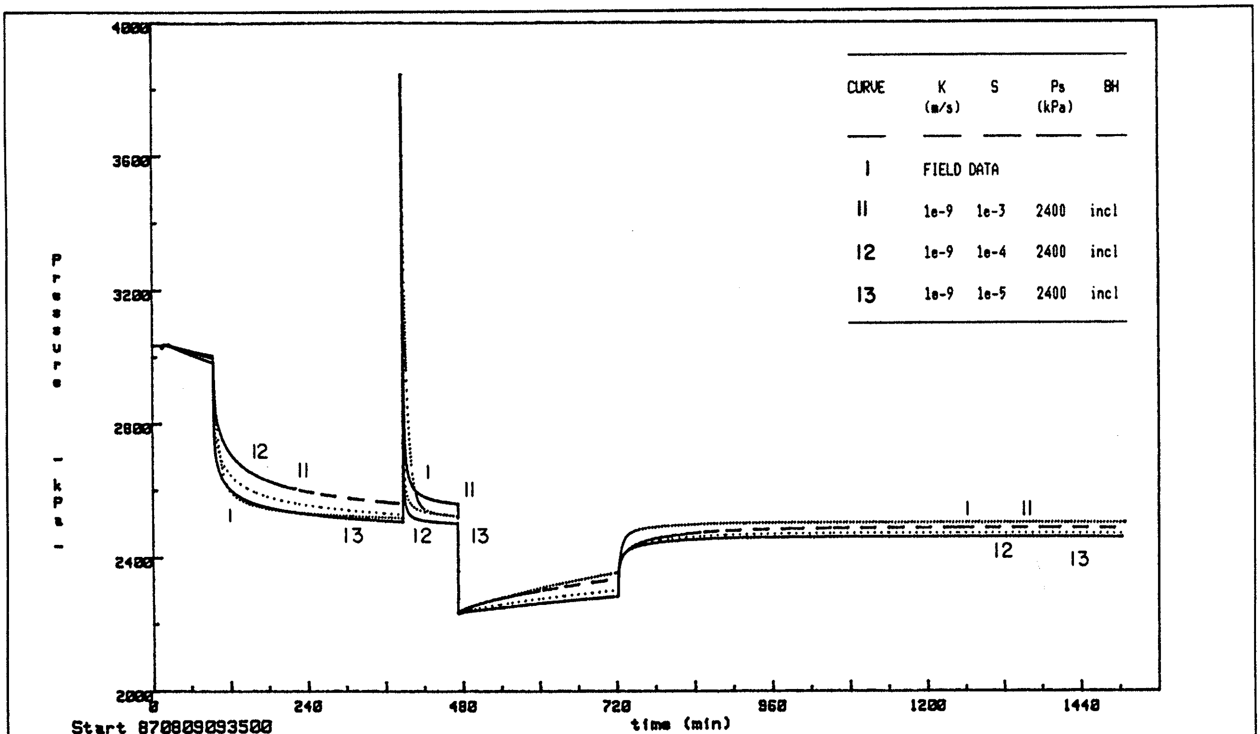
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	6.26(b)

SENSITIVITY ANALYSES AT A HYDRAULIC CONDUCTIVITY OF 1e-10 m/s SA/311.0D



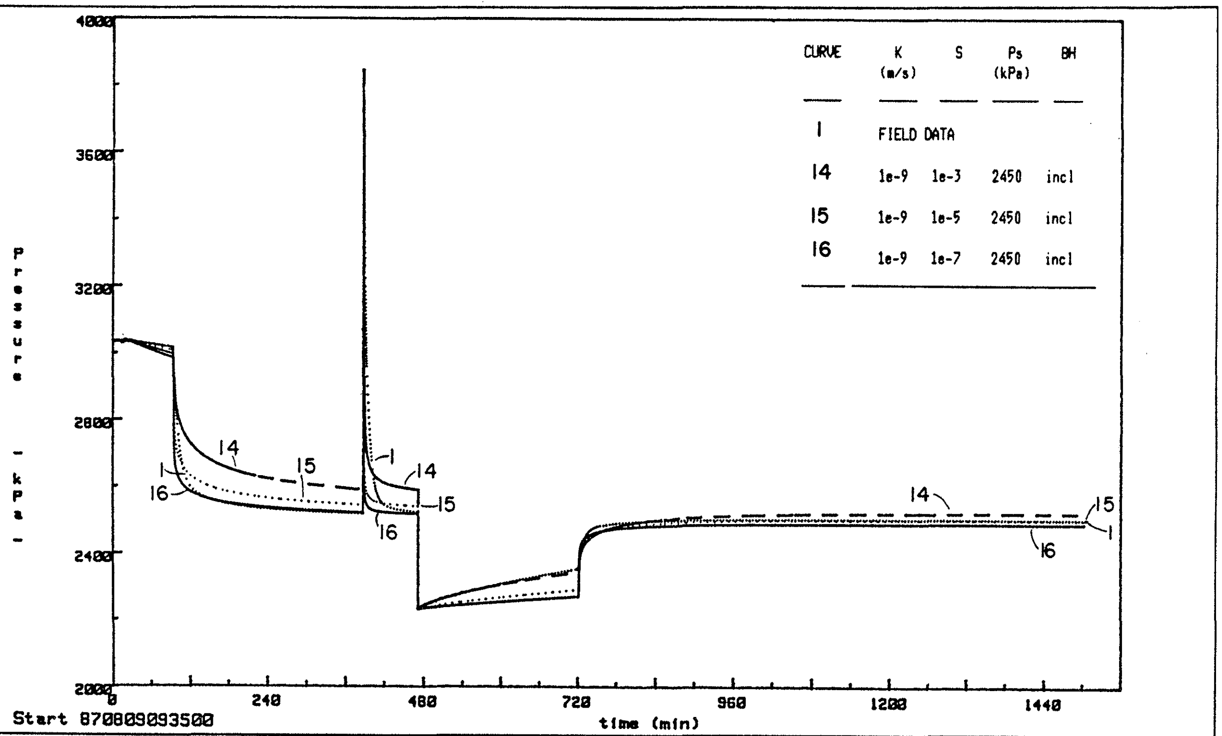
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.27

STORATIVITY SENSITIVITY AT A HYDRAULIC CONDUCTIVITY OF 1e-9 m/s AND A STATIC PRESSURE OF 2505 kPa SA/311.0D



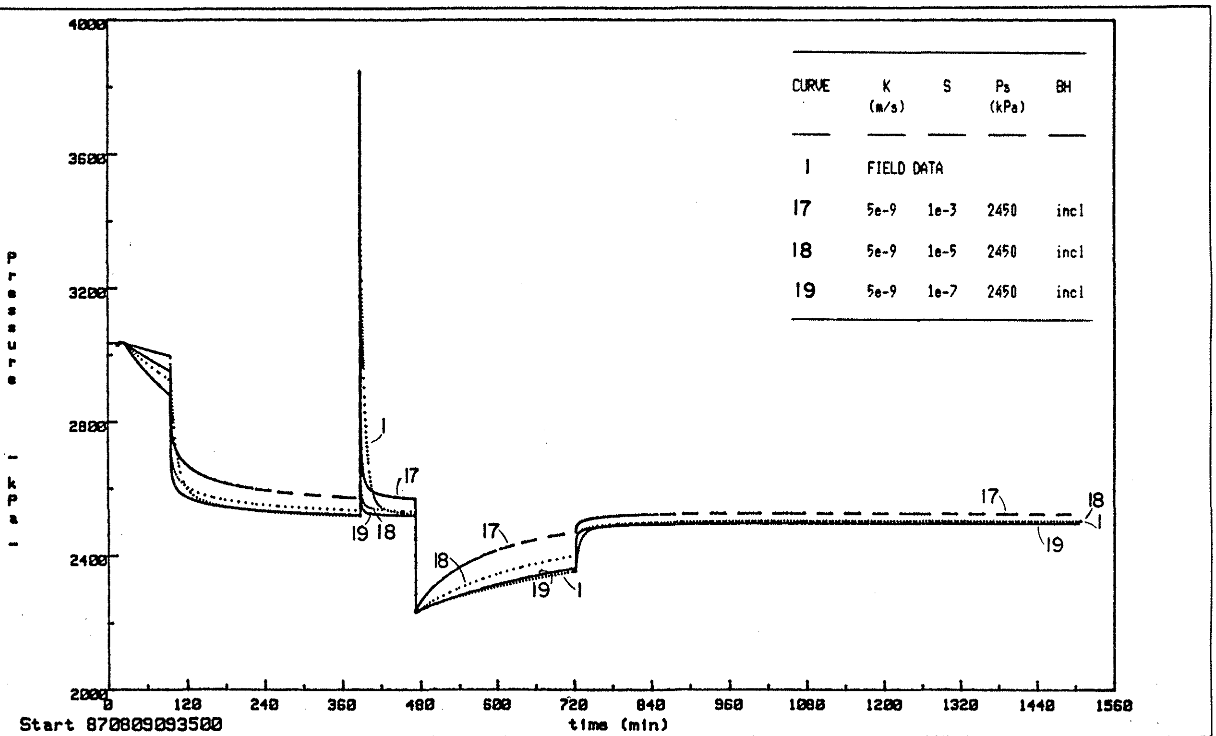
NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.28

STORATIVITY SENSITIVITY AT A HYDRAULIC CONDUCTIVITY OF 1e-9 m/s AND A STATIC PRESSURE OF 2400 kPa SA/311.0D



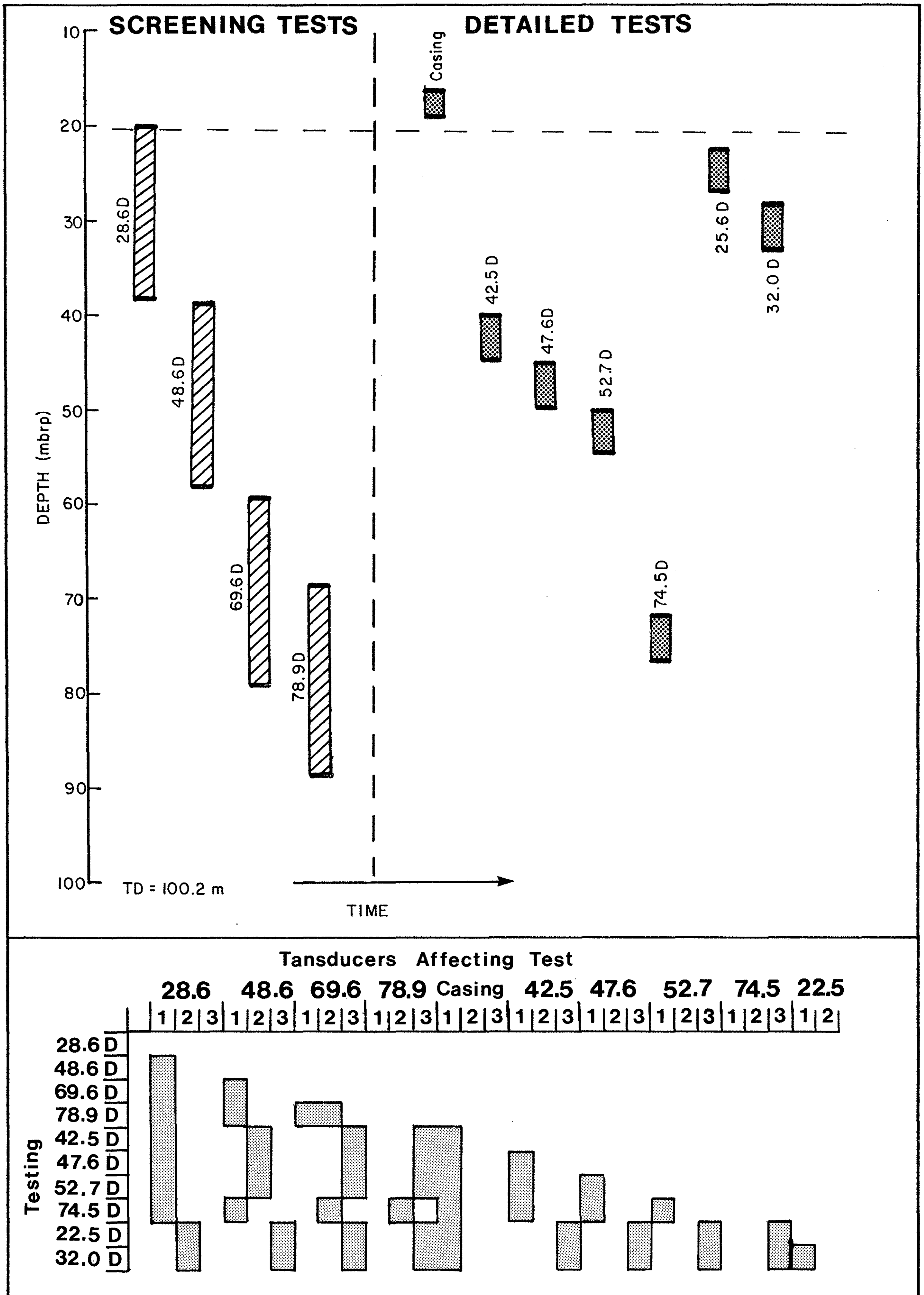
NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.29

STORATIVITY SENSITIVITY AT A HYDRAULIC CONDUCTIVITY OF **1e-9** m/s AND A STATIC PRESSURE OF 2450 kPa SA/311.0D



NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 6.30

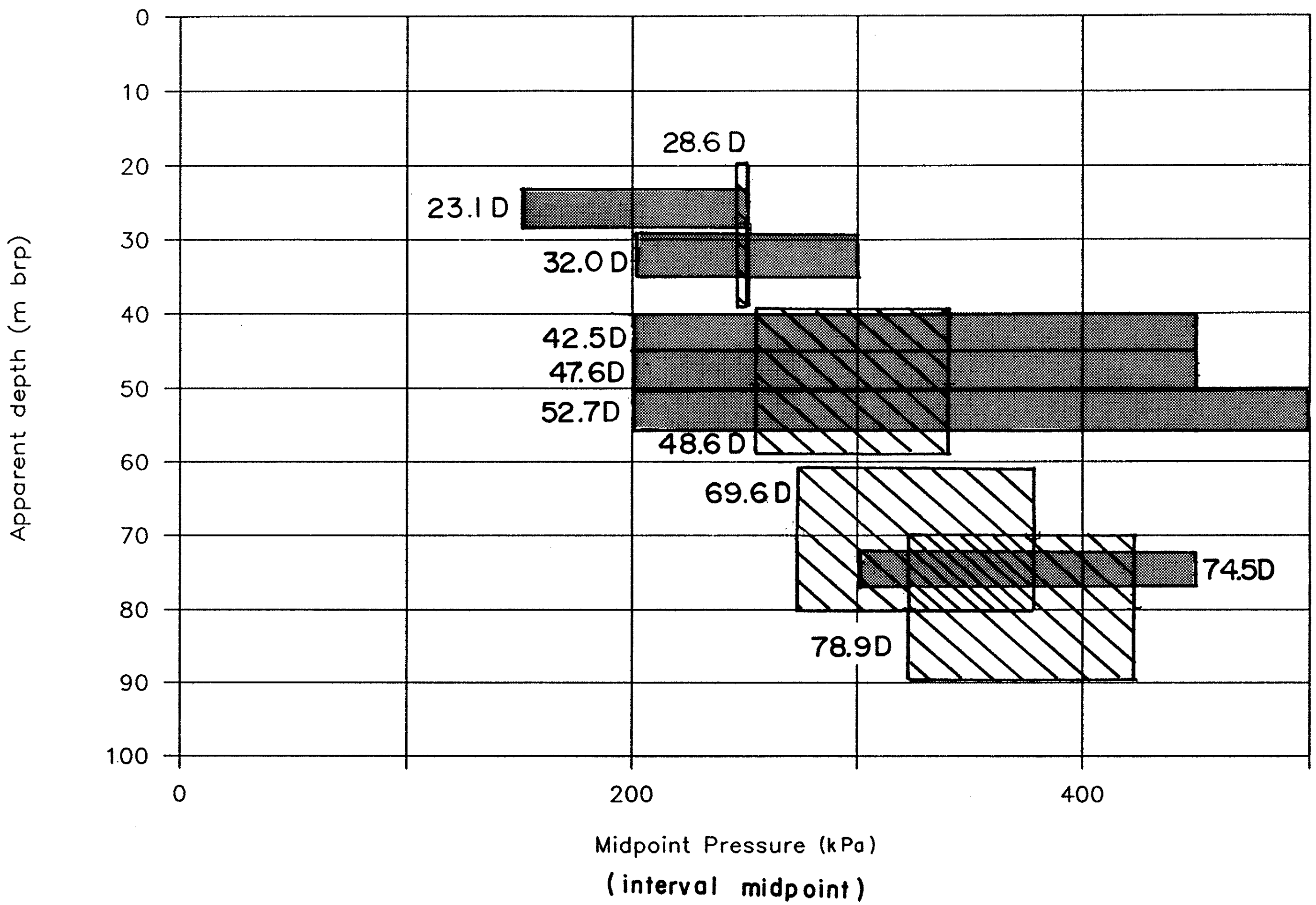
STORATIVITY SENSITIVITY AT A HYDRAULIC CONDUCTIVITY OF **5e-9** m/s AND A STATIC PRESSURE OF 2450 kPa SA/311.0D



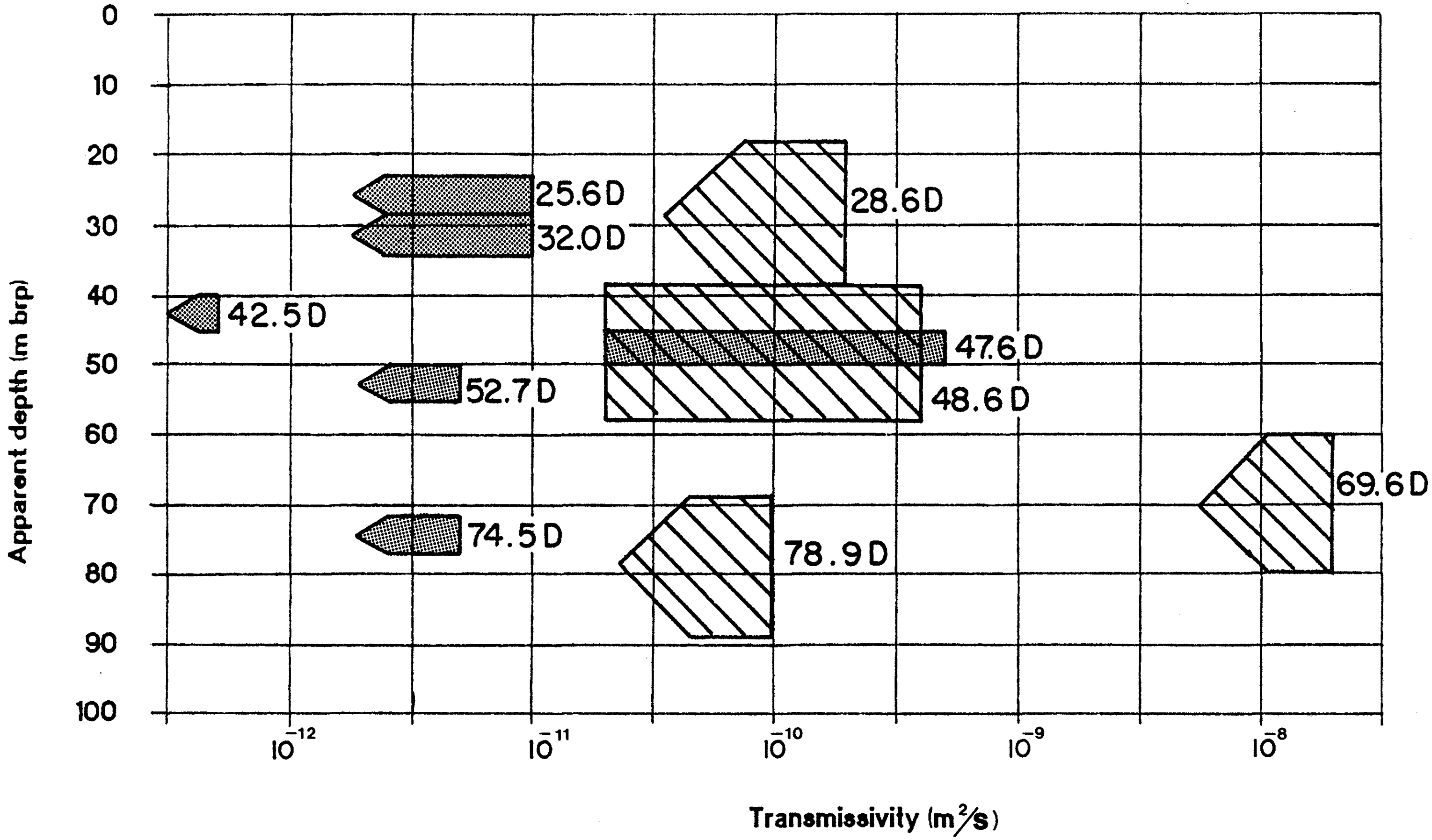
NAGRA / GLAG NTB: 88-03

TESTING AND PRESSURE DEPENDENCY - HVB

OBERBAUENSTOCK | DAT.: APR. 88 | 7.1

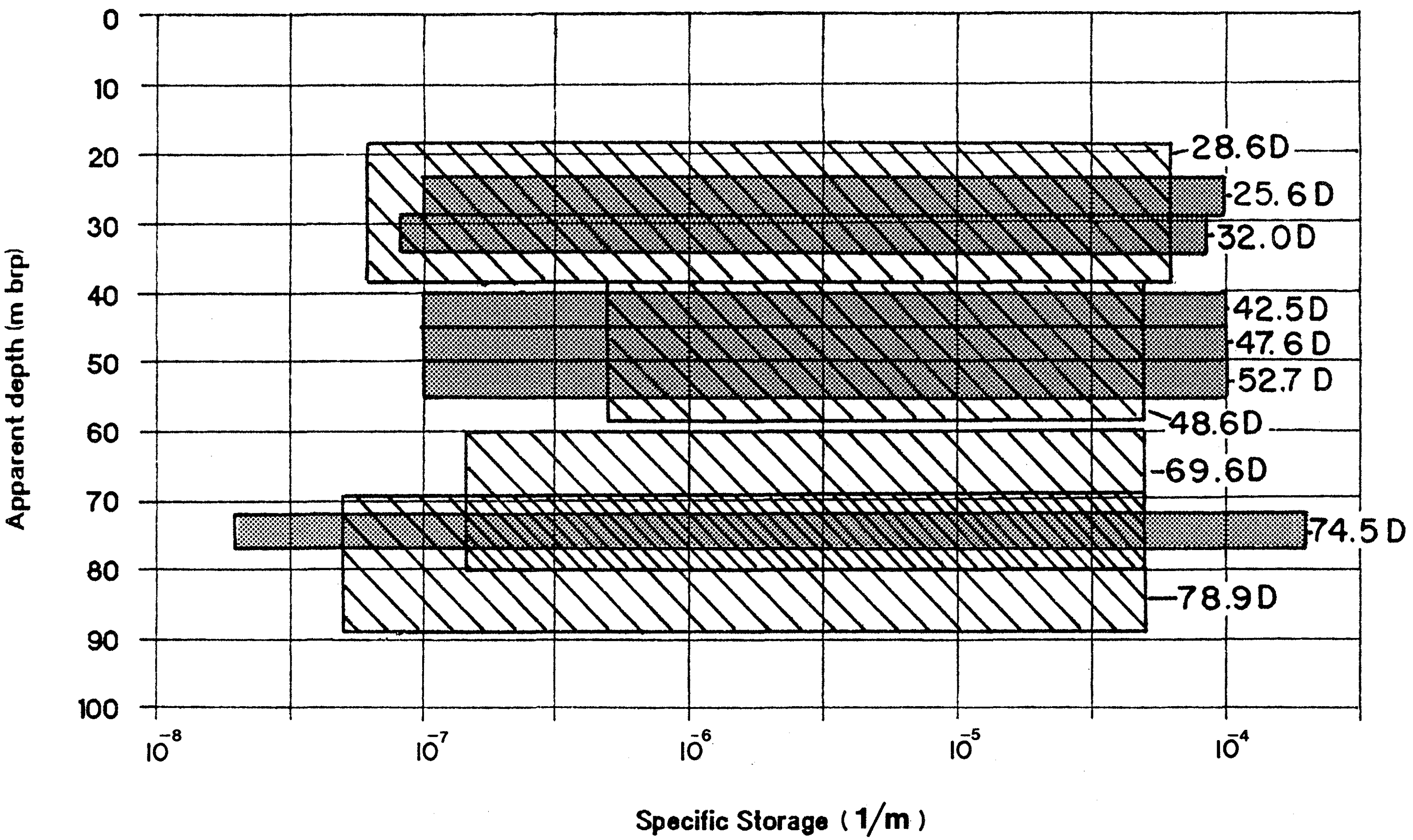


NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	7.2
HVB - PRESSURE PROFILE (P2)			



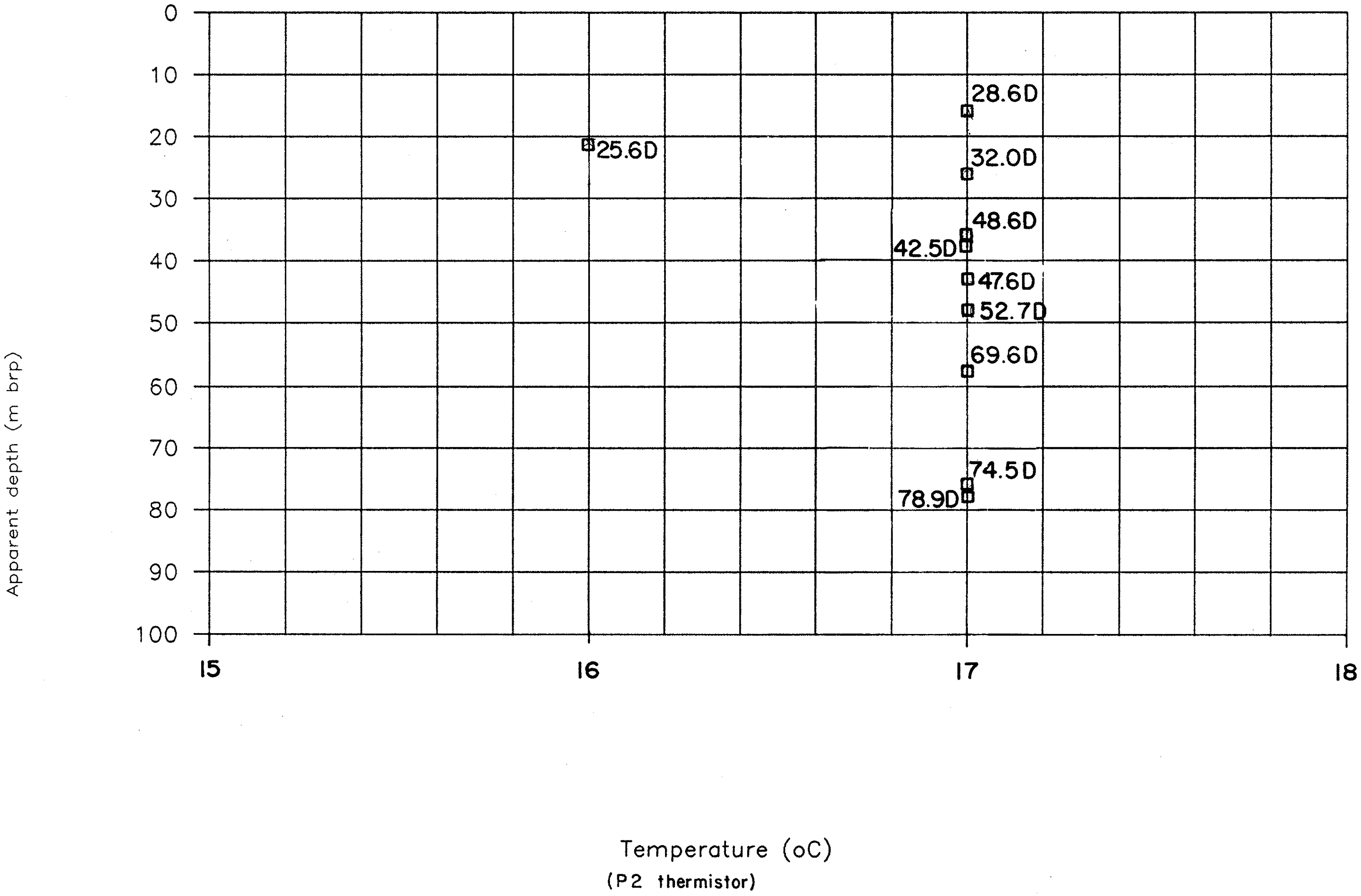
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	7.3

HVB - TRANSMISSIVITY PROFILE



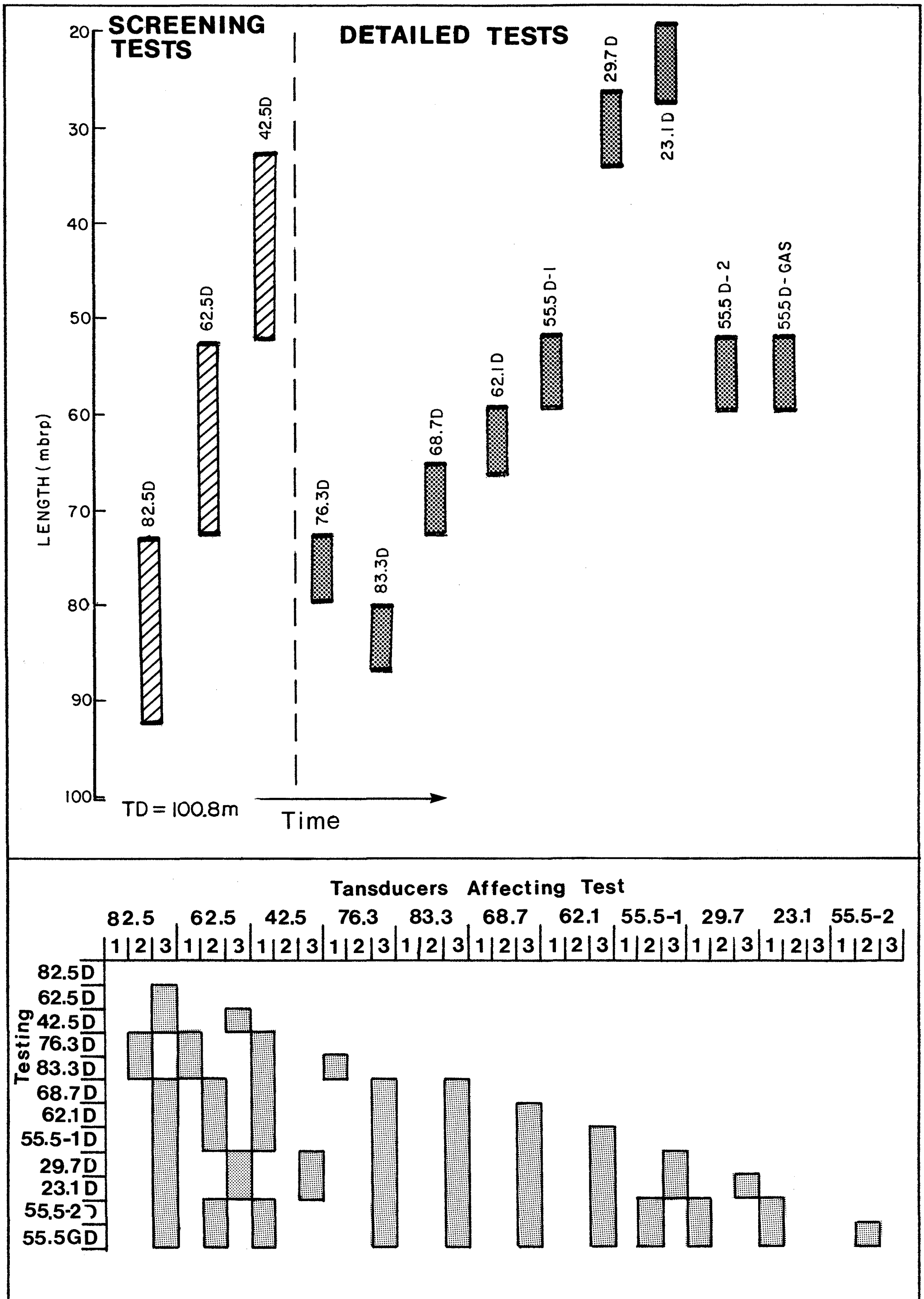
NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	7.4

HVB - SPECIFIC STORAGE PROFILE



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	7·5

HVB - TEMPERATURE PROFILE



NAGRA / GLAG

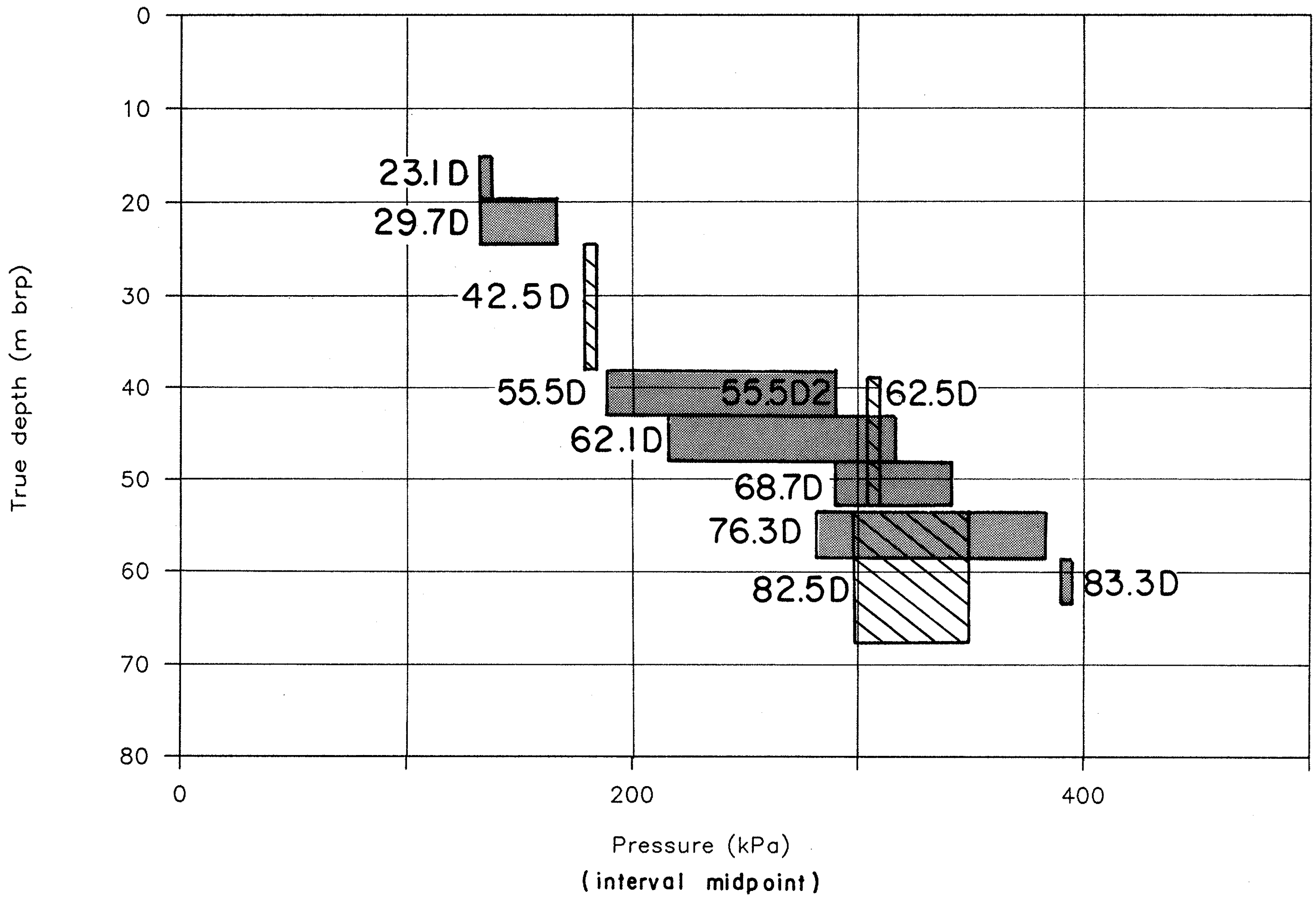
NTB: 88-03

TESTING AND PRESSURE DEPENDENCY - HBG

OBERBAUENSTOCK

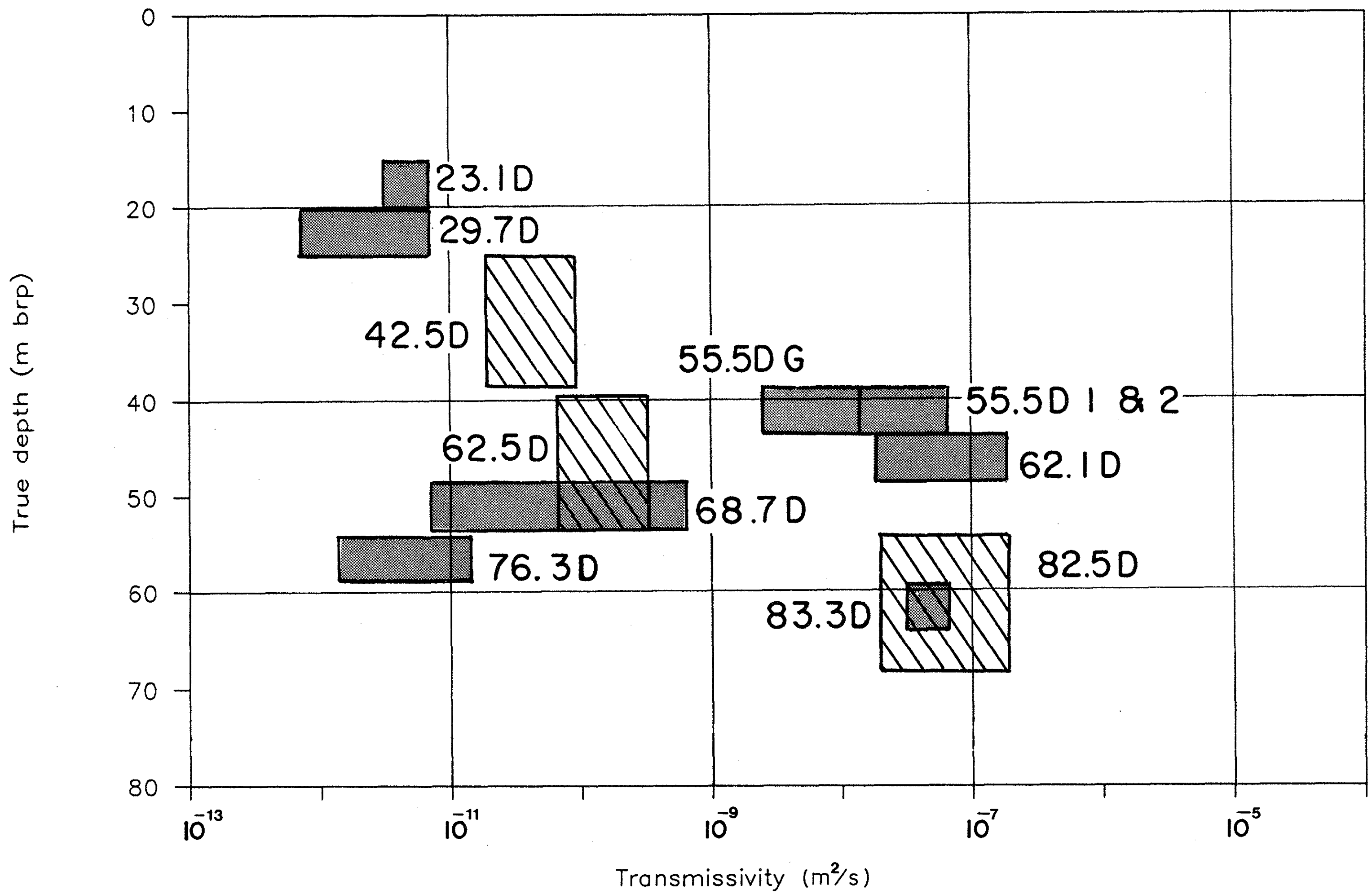
DAT.: APR. 88

8.1

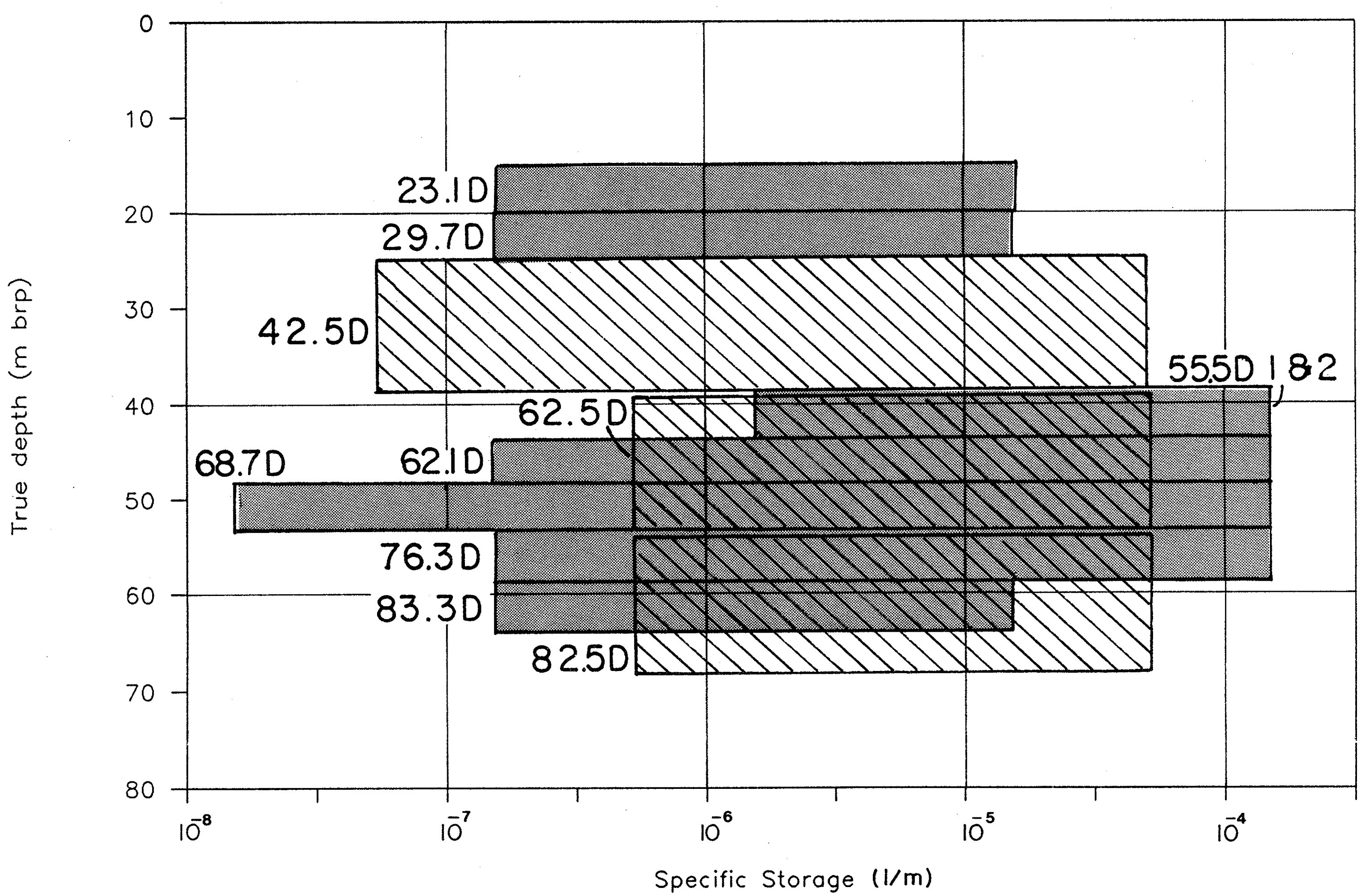


NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 8.2

HGB - PRESSURE PROFILE (P2)

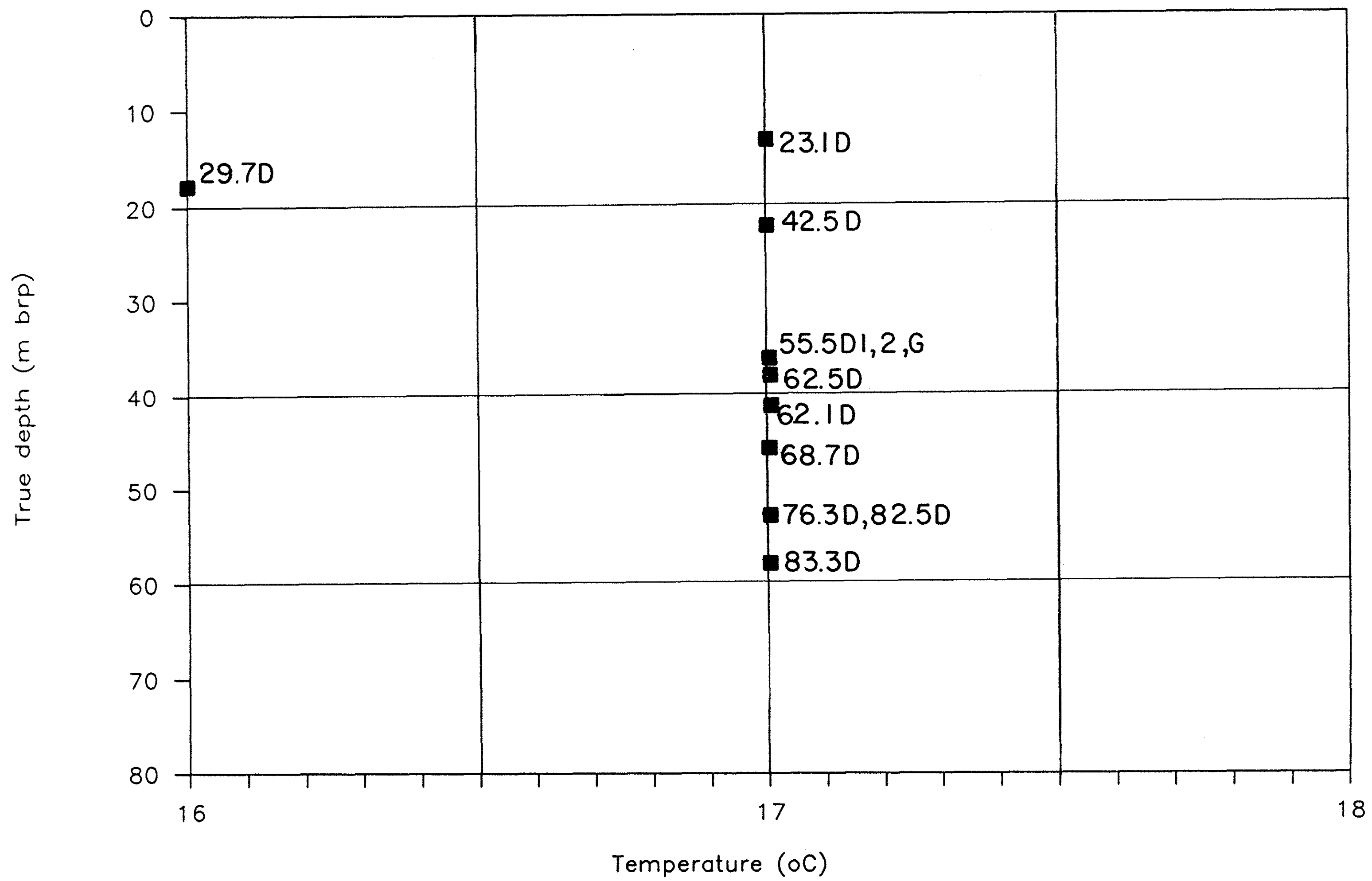


NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	8.3
HGB - TRANSMISSIVITY PROFILE				



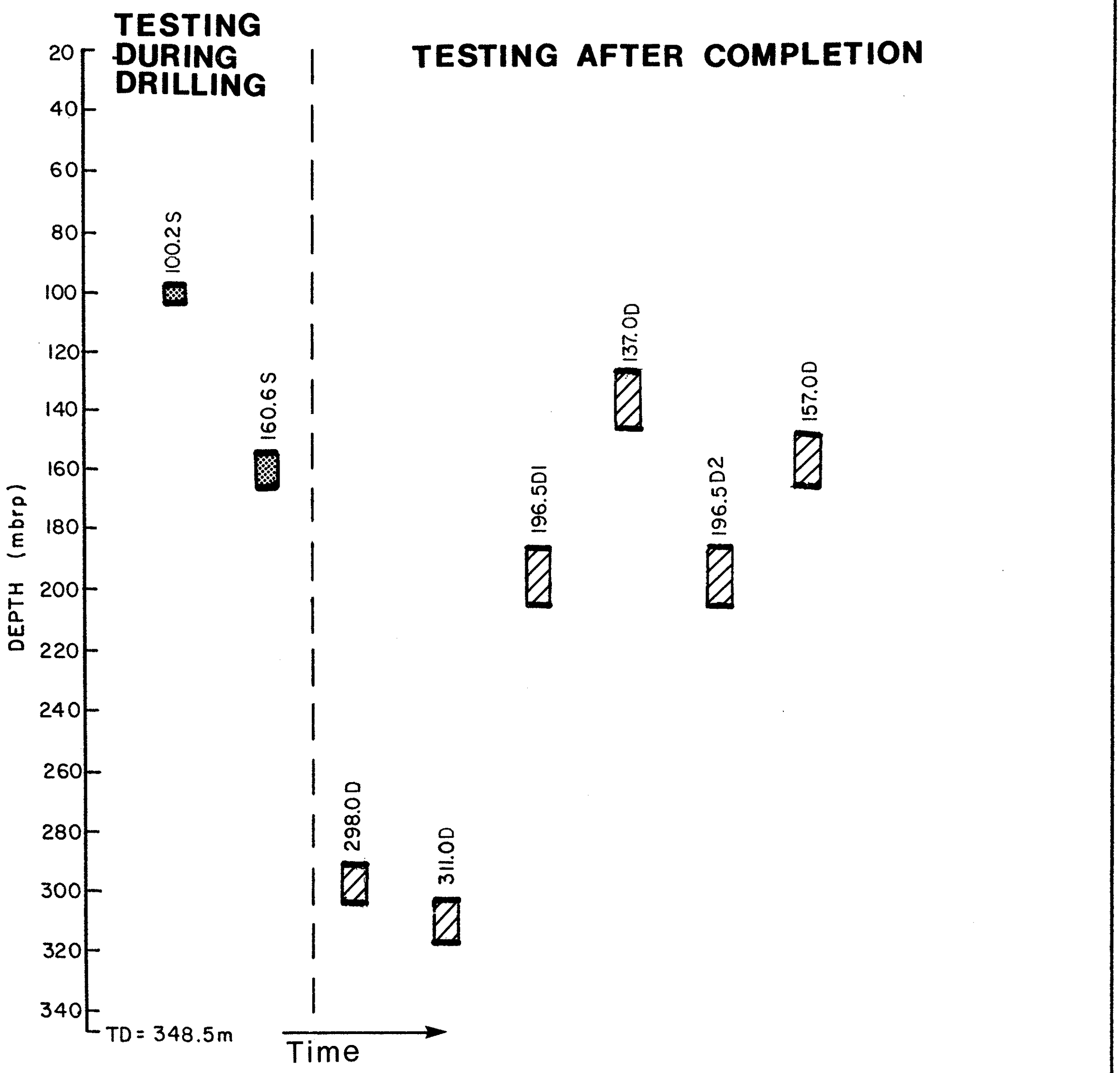
NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	8.4

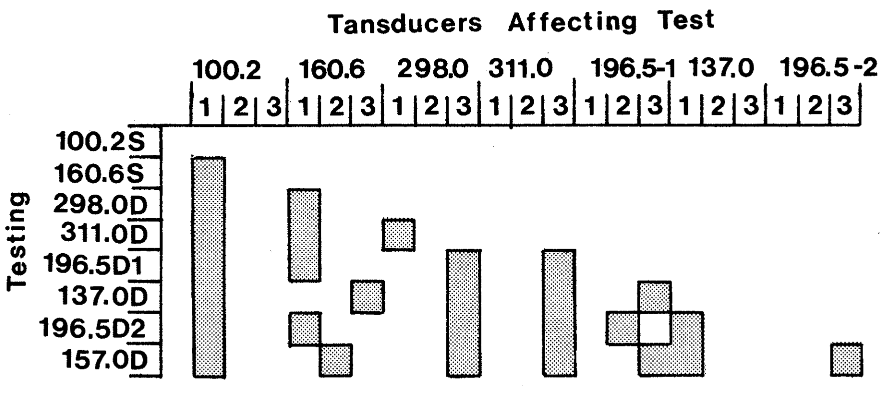
HGB - SPECIFIC STORAGE PROFILE



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	8.5

HGB - TEMPERATURE PROFILE

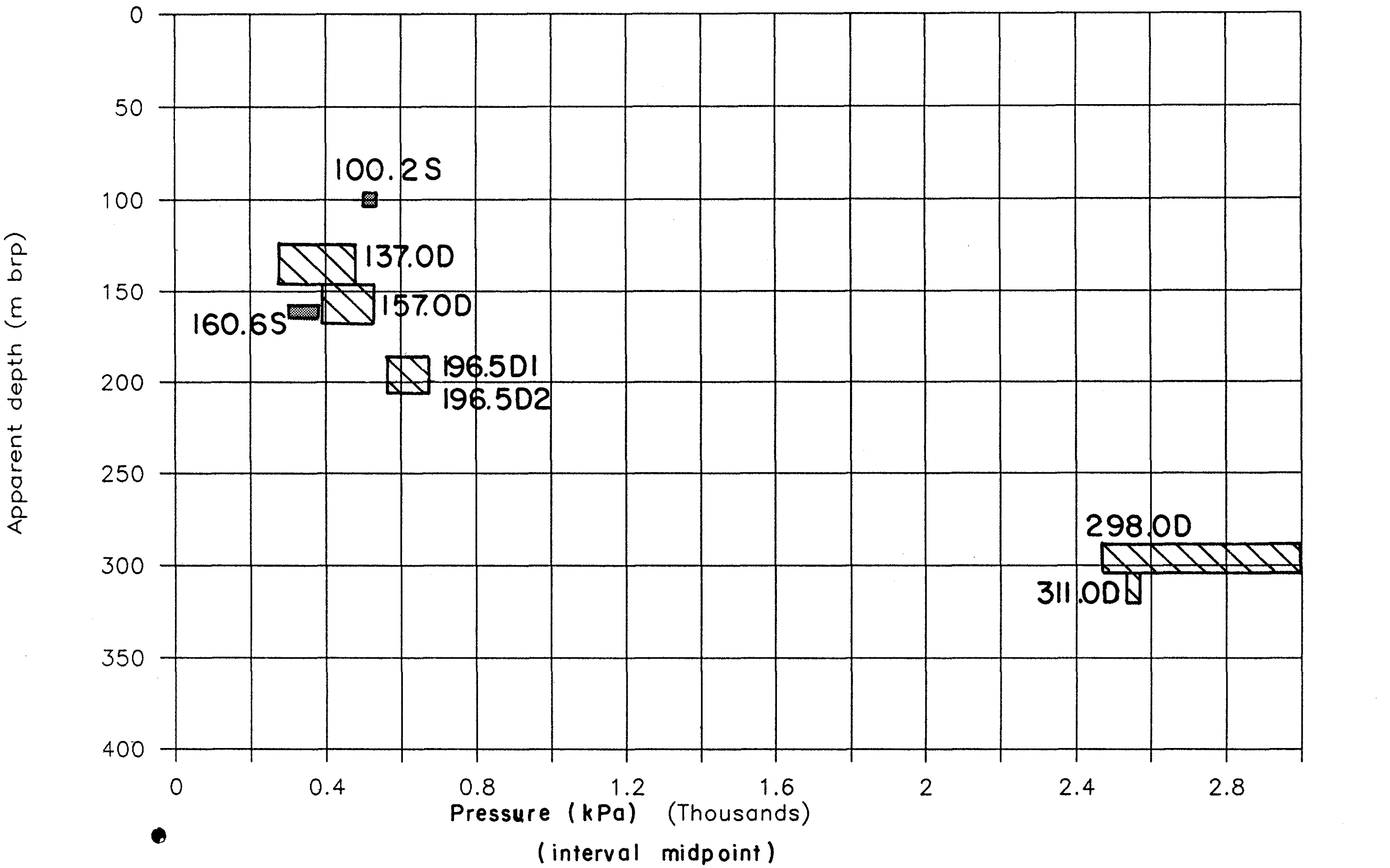




NAGRA / GLAG NTB:88-03

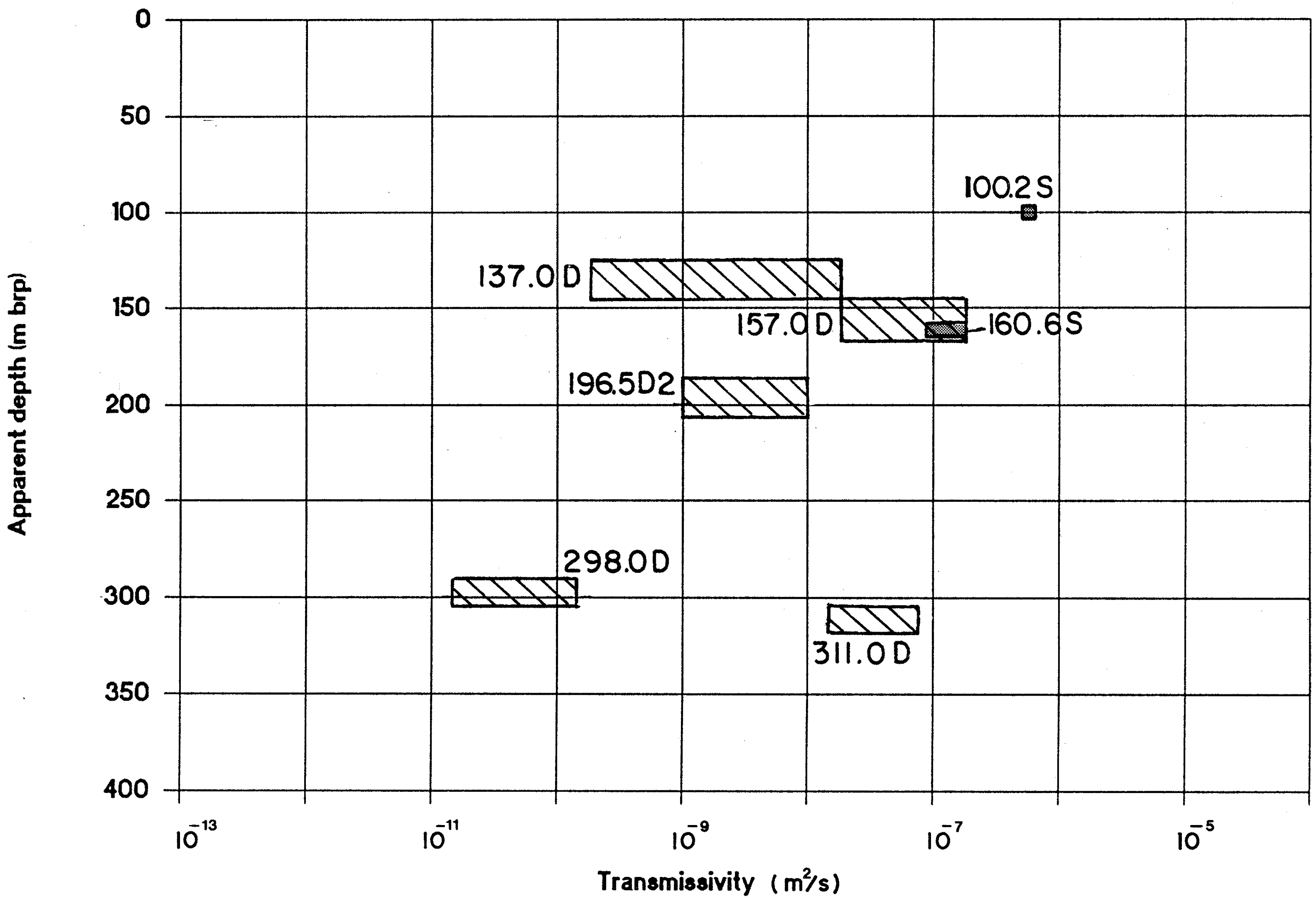
TESTING AND PRESSURE DEPENDENCY - SA

OBERBAUENSTOCK	DAT.: APR. 88	9.1



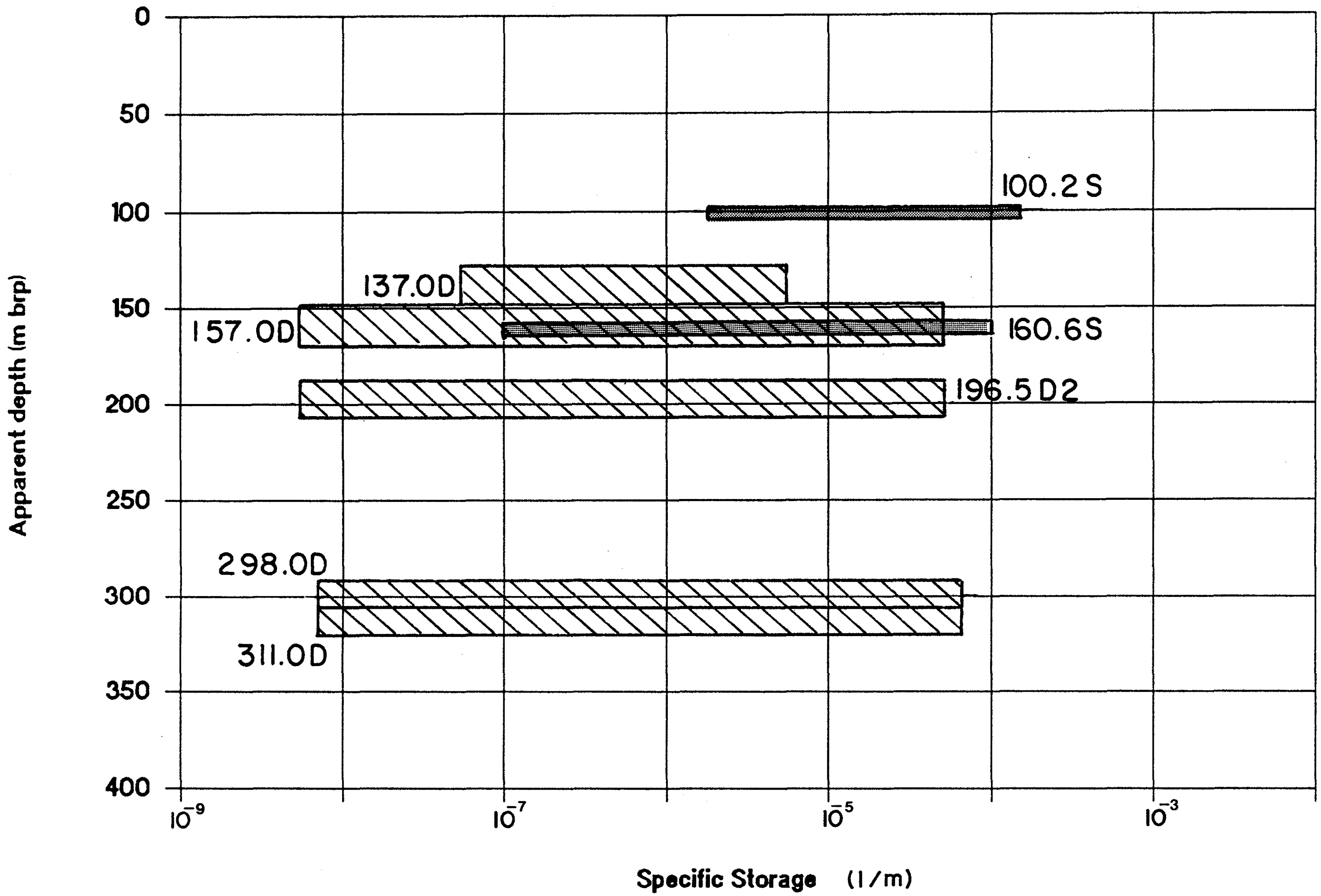
NAGRA / GLAG NTB:88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 9.2

SA - PRESSURE PROFILE (P2)



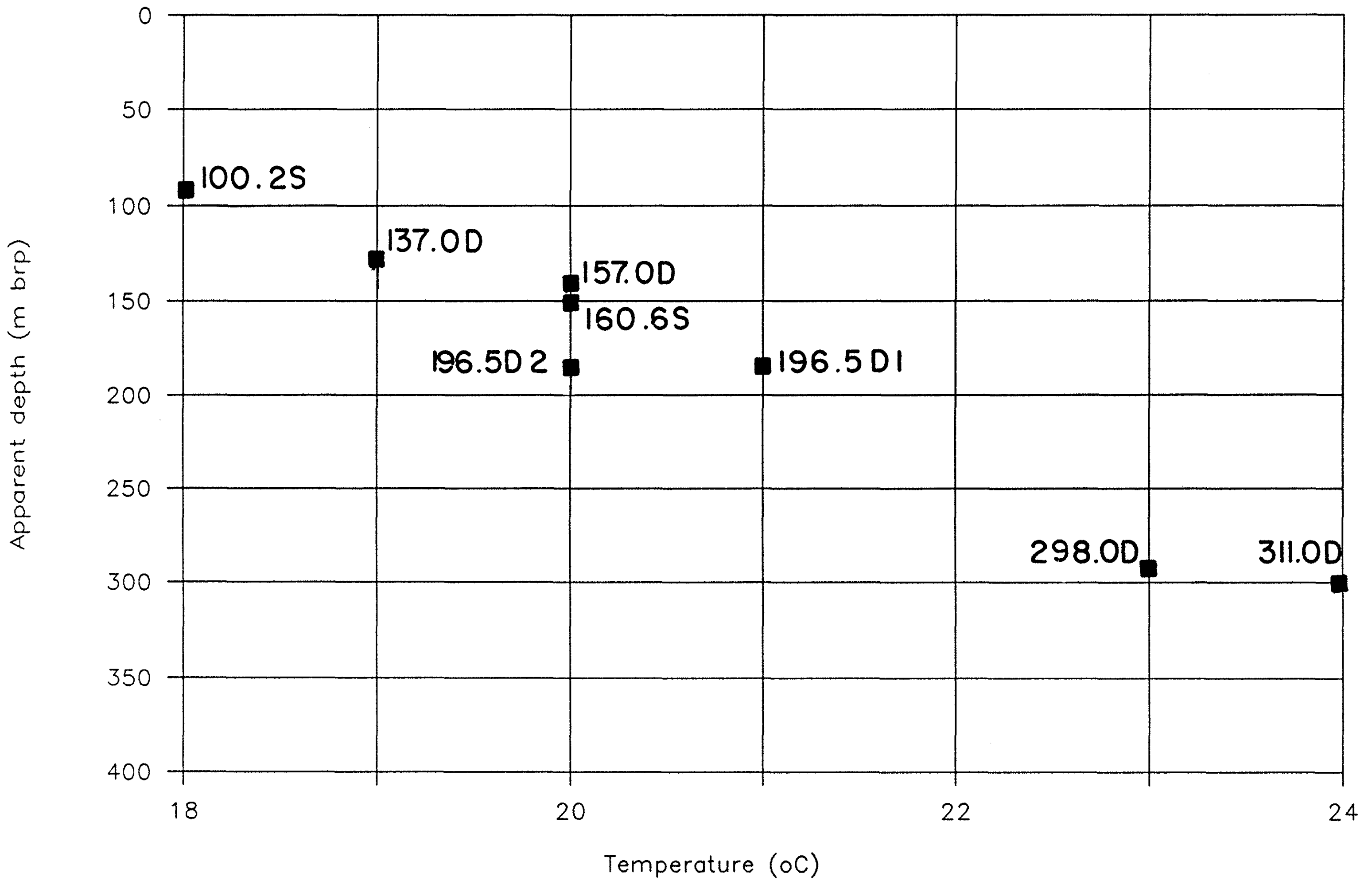
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	9.3

SA - TRANSMISSIVITY PROFILE



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	9.4

SA - SPECIFIC STORAGE PROFILE



NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | 9.5

SA - TEMPERATURE PROFILE

TEXT TABLES

Table 1.1: Borehole and Testing Activity Summary

Borehole	Inclination	Diameter (2) (mm)	Depth (m)	Testing Intervals	Sampled Intervals
HVB	90°	96	100.2	10	0
HGB	49° (1)	96	100.8	12	1
SA	90°	96	348.8	8	1
		TOTAL	549.8	30	2

(1) Nominal inclination for HGB was 45°. Actual inclination was 49° +/- from horizontal

(2) Nominal drilled diameter in testing and sampling intervals

Table 3.1: Performance Specifications of BPT/Lynes Pressure/Temperature Instrumentation

	TCWL Pressure	TCWL Temperature	SPP Pressure	SPP Temperature
TYPE	QUARTZ (with temp. compensation)	THERMISTOR	QUARTZ (with temp. compensation)	THERMISTOR
RANGE	0 to 345 bar	0 to 105° C	0 to 345 bar	0 to 95° C
RESOLUTION	0.005% FS	0.1° C	0.005% FS	0.1° C
ACCURACY	0.05% FS	1° C	0.05% FS	1° C
DIMENSIONS	TCWL sensor unit		SPP unit	
LENGTH/HEIGHT	1.15 m		0.12 m	
DIAMETER	42 m		1.50 mm	
DATA CABLE	Single conductor		Single conductor	
DATA SIGNAL	Frequency		Frequency	

Table 3.2: Flow Meter Specifications

No.	Model	Flow Minimum (ml/min)	Flow Maximum (ml/min)	Accuracy (% F.S.)	Flow Sensor Diameter (mm)
1	D6	0.1	20	0.4	1.6
2	D6	20	400	0.4	1.6
3	D25	400	8000	0.4	6.4
4	D25	400	8000	0.4	6.4

Notes:

Manufacturer : Micromotion Inc., Boulder, Colorado
Operating Pressure: 193 bars
Power: 115 V or 220 V switchable with cord
Output Signal: Analog-Analog
Sensor Housing: NEMA IV Aluminum Housings
Wetted Parts: 316L Stainless Steel
Data Display: Programmable digital rate/totalizer display
Data Process: RS232C Interface with Digital Output to the HP 320 System

Table 3.3: Injection Pump Specifications

Pump Model	J-7143-92	J-7138-70
SPECIFICATIONS		
Supplier	Cole-Parmer (Chicago, IL)	Cole-Parmer (Chicago, IL)
Minimum Flow (ml/min)	0.2	100
Maximum Flow (ml/min)	10	1000
Mechanism type	Dual Piston	Diaphragm
Adjustment Method	Stroke length	Stroke length
Stroke Length	6.4	N/S
Power	Built in 220 V motor	Added 220 V 1/3 H.P. motor
Length (mm)	241	N/S
Width (mm)	178	N/S
Height (mm)	159	N/S
Weight (kg)	5.8	30
Maximum Pressure (bar)	345	28
Maximum Temperature (°C)	93	93
Wetted Parts	316 SS	316 SS

Note: N/S - Not Specified

Table 3.4: Data Acquisition System Components

1) Computer System

- 1 HP320SP/Computer/Unix-based Software
- 1 HP9133L 40MB Hard Disk/3 1/2" Drive
- 1 HP98568A Expander Chassis
- 1 HP35731A 12" Monochrome Monitor
- 1 Eventide 4MB RAM Memory Board
- 1 HP46021A HPIL Keyboard
- 1 HP98542A Video Board

2) Data Acquisition System

- 2 BPT/Lynes Signal Converters (SC2)
- 2 HP5316A Universal Counter
- 1 Micromotion Digital Rate Totalizer
- 1 HP98620B DMA Controller
- 1 HP98625A HP-1B High Speed Interface
- 1 HP98642A MUX

3) Peripherals

- 1 HP98286S DOS Coprocessor
- 1 HP9127A 5 1/4" Disk Drive
- 1 HP7475A 6-Pen Plotter (Analysis)
- 1 HP2225A Think Jet Printer (Analysis)
- 1 HP7470A 2-Pen Plotter (Real Time Data)
- 1 EPSONLX80 Printer (Real Time Data)

Table 3.5: OBS-1 Interval Test Event Inventory

Borehole	Interval (1)	INF	COM	Psr	P-F	P-T	Si	Sw	Pr	Qcr	Qcp	SAM	DEF	Event Totals
		Event Types (2)												
HVB	28.6D-SCR	1	1	1	1		1	1	2				1	9
10 Intervals	48.6D-SCR	1	1	1	1		1	1	2				1	9
	69.6D-SCR	1	1	1	1		1		1				1	7
	78.9D-SCR	1	1	1	1	1							1	6
	42.5D_DET	1	1	1	1								1	5
	47.6D-DET	1	1	1	1	1			2	2			1	10
	52.7D-DET	1	1	1	1	1							1	6
	74.5D-DET	1	1	1	1								1	5
	25.6D-DET	1	1	1	1	1			2		1		1	9
	32.0D-DET	1	1	1	1								1	5
HGB	82.5D-SCR	1	1	1	5		2		3	1			1	15
12 Intervals	62.5D-SCR	1	1	1	2				3	3			1	12
	42.5D-DET	1	1	1	1	1							1	6
	76.3D-DET	1	1	1	1								1	5
	83.3D-DET	1	1	1	1		1	1	2			2	1	11
	68.7D-DET	1	1	1	2	1		1	2				1	10
	62.1D-DET	1	1	1	1	1			1				1	7
	55.5D1-DET	1	1	1	1	1	1	1	3				1	11
	29.7D-DET	1	1	1	2								1	6
	23.1D-DET	1	1	1	2								1	6
	55.5D2-DET	1	1	2	1		1		1					7
	55.5D-GAS								3	4			1	8
SA	100.2S-DET	1	1	1				1	1			3	1	9
8 Intervals	160.6S-DET	1	1	1			2	1	2		1		1	10
	298.0D-DET	1	1	1	2			1	1				1	8
	311.0D-DET	1	1	1	1			1	1				1	7
	196.5D1-DET	1	1	1									1	4
	137.0D-DET	1		1				1	1				1	5
	196.5D2-DET	1		1	2			1	1				1	7
	157.0D-DET	1		1				2	4		3		1	12
	TOTALS	29	26	30	34	8	10	13	38	10	5	5	29	

Total Intervals: 30

Notes:

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(1) Interval: SCR - Screening; DET - Detailed

(2) Test Types:

INF	Inflation	COM	Compliance
P-F	Pulsetest with FAV	Psr	Shut-in Pressure Recovery
Si	Slug Injection	P-T	Pulse Test with HVT
Pr	Pressure Recovery	Sw	Slug Withdrawal
Qcp	Constant Pressure Flow Test	Qcr	Constant Rate Flow Test
DEF	Deflation	SAM	Sampling

Table 4.1: Field Analysis Methods

Pulse/Slug	1) CBP Type Curves 2) Wellbore Model-Glimpse
Constant Rate Flow	1) Theis/Cooper-Jacob 2) Wellbore Model-Glimpse
Constant Head Flow	1) Match Flux Using Wellbore Model-Glimpse
Recovery (after constant rate)	1) Theis/Cooper-Jacob/Horner 2) Wellbore Simulator
Recovery (after constant head)	1) Wellbore Model-Glimpse

Table 4.2 (a): Simple Borehole History, SA/160.6S

Activity Description			Start Date ddmmmyy	Start Time hh:mm:ss	Elapsed Time (s)	Elapsed Time (d)	Event Duration (s)	Measrd/ Estmt'd P (kPa)	Equiv. Fld Hght (arp) (m ARP)	Pressure Reading	Data Ref.
Intersect top of zone	(156.00)		22-JUL-87	07:30:00	0	0.00	0	1600.0	-0.2	1600.0	GL1
Intersect bottom of zone	(165.80)		22-JUL-87	17:30:00	36000	0.42	36000	1600.00	-0.2	1600.0	GL1
Stop drilling; pull rods			22-JUL-87	17:30:00	36000	0.42	0	1600.0	-0.2	1600.0	Gc2
Drill out			22-JUL-87	21:00:00	48600	0.56	12600	1000.0	-61.5	1000.0	Gc2
Start Prep.			22-JUL-87	21:00:00	48600	0.56	0	1000.0	-61.5	1000.0	Gc2
Stop Prep.			22-JUL-87	23:30:00	57600	0.67	9000	750.0	-87.0	750.0	Gc2
Start Run-In of Tool		OBS3/160.6S	22-JUL-87	23:30:00	57600	0.67	0	750.0	-87.0	750.0	Gc1
Tool on depth	P2	OBS3/160.6S	23-JUL-87	04:00:00	73800	0.85	16200	510.0	-111.5	510.0	GL1
Start Inf	P2	OBS3/160.6S	23-JUL-87	05:40:00	79800	0.92	6000	468.0	-115.8	468.0	GL1 GL1
End Inf	P2	OBS3/160.6S	23-JUL-87	05:44:00	80040	0.93	240	468.0	-115.8	468.0	GL1
Start Com	P2	OBS3/160.6S	23-JUL-87	05:44:00	80040	0.93	0	468.0	-115.8	468.0	GL1

DATA REFERENCES

Gc1 Gemag - drilling logs

Gc2 Gemag - field notes

GL1 GLAG - field data

Table 4.2 (b) Complex Borehole History, HVB/52.7D

Activity Description			Start Date ddmmmyy	Start Time hh:mm:ss	Elapsed Time (s)	Elapsed Time (d)	Event Duration (s)	Measrd/ Estmt'd P (kPa)	Equiv. Fld Hght (arp) (m BRP)	Pressure Reading	Data Ref.
Intersect top of zone (50.12)		OBS1/52.7D	23-MAY-87	03:55:00	0	0.00	0	621.7	2.5	621.7	Gc1
Intersect bottom of zone (55.18)		OBS1/52.7D	23-MAY-87	06:12:00	8220	0.10	8220	631.6	2.5	631.6	Gc1
End of coring TD (100.2)		OBS1/52.7D	25-MAY-87	06:00:00	180300	2.09	172080	641.4	2.5	641.4	Gc1
End of mud circulation		OBS1/52.7D	25-MAY-87	06:30:00	182100	2.11	1800	592.2	2.5	592.2	Gc1
Start INTGEC logging			25-MAY-87	09:00:00	191100	2.21	9000	578.7	1.1	578.7	Gc2
End INTGEC logging			25-MAY-87	22:00:00	237900	2.75	46800	578.7	1.1	578.7	Gc2
Start WKB logging			25-MAY-87	22:00:00	237900	2.75	0	578.7	1.1	578.7	Gc2
End WKB logging			26-MAY-87	18:30:00	311700	3.61	73800	578.7	1.1	578.7	Gc2
Start BPB logging			26-MAY-87	19:00:00	313500	3.63	1800	578.7	1.1	578.7	Gc2
End BPB logging			27-MAY-87	13:00:00	378300	4.38	64800	578.7	1.1	578.7	Gc2
Start Run-In	P1	OBS1/28.6D	27-MAY-87	20:00:00	403500	4.67	25200	273.3	1.9	586.2	GL1
At Depth (P1)	P1	OBS1/28.6D	27-MAY-87	23:50:00	417300	4.83	13800	273.3	1.9	586.2	GL1
Inflation	P1	OBS1/28.6D	28-MAY-87	00:32:00	419820	4.86	2520	273.3	1.9	586.2	GL1
Start Compliance period (P1)	P1	OBS1/28.6D	28-MAY-87	00:36:00	420060	4.86	240	277.4	2.3	590.3	GL1
Start pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	03:52:00	431820	5.00	11760	271.8	1.7	584.7	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	04:30:00	434100	5.02	2280	224.9	-3.1	537.8	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	05:30:00	437700	5.07	3600	183.0	-7.3	495.9	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	06:30:00	441300	5.11	3600	153.7	-10.3	466.6	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	08:00:00	446700	5.17	5400	122.0	-13.5	434.9	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	09:30:00	452100	5.23	5400	102.6	-15.5	415.5	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	28-MAY-87	11:15:00	458400	5.31	6300	85.1	-17.3	398.0	GL1
Contd pressure falloff (P1)	P1	OBS1/28.6D	29-MAY-87	02:31:00	513360	5.94	54960	14.7	-24.5	327.6	GL1
Start packer deflation (P1)	P1	OBS1/28.6D	29-MAY-87	02:31:00	513360	5.94	0	256.5	0.2	569.4	GL1
End Packer Deflation (P1)	P1	OBS1/28.6D	29-MAY-87	02:33:00	513480	5.94	120	256.5	0.2	569.4	GL1
End Test	P1	OBS1/28.6D	29-MAY-87	03:10:00	515700	5.97	2220	252.2	-0.3	565.1	GL1
Start run-in	P1	OBS1/28.6D	29-MAY-87	04:10:00	519300	6.01	3600	239.7	-1.5	552.6	GL1
On depth (Open SI - FAV)	P2	OBS1/48.6D	29-MAY-87	05:29:00	524040	6.07	4740	464.8	1.7	584.4	GL1
Start packer inflation	P2	OBS1/48.6D	29-MAY-87	07:00:00	529500	6.13	5460	456.1	0.8	575.7	GL1
Contd packer inflation	P2	OBS1/48.6D	29-MAY-87	07:52:00	532620	6.16	3120	473.7	2.6	593.3	GL1
End packer inflation	P2	OBS1/48.6D	29-MAY-87	08:21:41	534401	6.19	1781	473.7	2.6	593.3	GL1
Start Compliance period	P2	OBS1/48.6D	29-MAY-87	08:21:41	534401	6.19	0	473.7	2.6	593.3	GL1
End Compliance period	P2	OBS1/48.6D	29-MAY-87	10:03:27	540507	6.26	6106	472.7	2.5	592.3	GL1
Start Psr (Close SI - FAV)	P2	OBS1/48.6D	29-MAY-87	10:03:27	540507	6.26	0	472.7	2.5	592.3	GL1
Psr	P2	OBS1/48.6D	29-MAY-87	10:15:00	541200	6.26	693	424.9	-2.4	544.5	GL1
Psr	P2	OBS1/48.6D	29-MAY-87	10:30:00	542100	6.27	900	399.1	-5.0	518.7	GL1
End Psr	P2	OBS1/48.6D	29-MAY-87	11:10:27	544527	6.30	2427	377.2	-7.2	496.8	GL1
Start Pi1	P2	OBS1/48.6D	29-MAY-87	11:10:27	544527	6.30	0	470.2	2.3	589.8	GL1
Pi1	P2	OBS1/48.6D	29-MAY-87	11:22:00	545220	6.31	693	395.3	-5.4	514.9	GL1
End Pi1	P2	OBS1/48.6D	29-MAY-87	11:35:51	546051	6.32	831	380.4	-6.9	500.0	GL1
Start Si1 (Open SI - FAV)	P2	OBS1/48.6D	29-MAY-87	11:35:51	546051	6.32	0	470.5	2.3	590.1	GL1
End Si1	P2	OBS1/48.6D	29-MAY-87	11:48:53	546833	6.33	782	470.1	2.2	589.7	GL1
Start Pr1 (Close SI - FAV)	P2	OBS1/48.6D	29-MAY-87	11:48:53	546833	6.33	0	470.1	2.2	589.7	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	11:52:00	547020	6.33	187	442.9	-0.5	562.5	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	12:00:00	547500	6.34	480	412.7	-3.6	532.3	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	12:15:00	548400	6.35	900	389.2	-6.0	508.8	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	13:00:00	551100	6.38	2700	369.0	-8.1	488.6	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	14:45:00	557400	6.45	6300	347.2	-10.3	466.8	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	17:15:00	566400	6.56	9000	326.0	-12.4	445.6	GL1
Pr1	P2	OBS1/48.6D	29-MAY-87	20:30:00	578100	6.69	11700	306.7	-14.4	426.3	GL1
Pr1	P2	OBS1/48.6D	30-MAY-87	00:30:00	592500	6.86	14400	289.2	-16.2	408.8	GL1
Pr1	P2	OBS1/48.6D	30-MAY-87	06:30:00	614100	7.11	21600	270.4	-18.1	390.0	GL1
Pr1	P2	OBS1/48.6D	30-MAY-87	12:30:00	635700	7.36	21600	256.3	-19.6	375.9	GL1
End Pr1	P2	OBS1/48.6D	30-MAY-87	15:03:05	644885	7.46	9185	251.2	-20.1	370.8	GL1
Start Sw1 (Open SI - FAV)	P2	OBS1/48.6D	30-MAY-87	15:03:05	644885	7.46	0	166.0	-28.8	285.6	GL1
End Sw1	P2	OBS1/48.6D	30-MAY-87	16:14:46	649186	7.51	4301	168.1	-28.6	287.7	GL1
Start Pr2 (Close SI - FAV)	P2	OBS1/48.6D	30-MAY-87	16:14:46	649186	7.51	0	168.1	-28.6	287.7	GL1
Pr2	P2	OBS1/48.6D	30-MAY-87	16:22:00	649620	7.52	434	179.9	-27.4	299.5	GL1
Pr2	P2	OBS1/48.6D	30-MAY-87	16:45:00	651000	7.53	1380	196.4	-25.7	316.0	GL1
Pr2	P2	OBS1/48.6D	30-MAY-87	17:15:00	652800	7.56	1800	204.8	-24.8	324.4	GL1
Pr2	P2	OBS1/48.6D	30-MAY-87	18:00:00	655500	7.59	2700	209.7	-24.3	329.3	GL1
End Pr2	P2	OBS1/48.6D	30-MAY-87	19:54:10	662350	7.67	6850	213.0	-24.0	332.6	GL1
Start Deflation	P2	OBS1/48.6D	30-MAY-87	19:54:10	662350	7.67	0	213.0	-24.0	332.6	GL1
End Deflation	P2	OBS1/48.6D	30-MAY-87	19:54:20	662360	7.67	10	213.0	-24.0	332.6	GL1
End Test	P2	OBS1/48.6D	30-MAY-87	19:58:30	662610	7.67	250	454.7	0.7	574.3	GL1
Packer Inflation (P3)	P3	OBS1/69.6D	30-MAY-87	21:00:00	666300	7.71	3690	666.4	1.5	582.1	GL1
Packer Deflation (P3)	P3	OBS1/69.6D	01-JUN-87	02:00:00	770700	8.92	104400	663.6	1.2	579.3	GL1
End Test	P3	OBS1/69.6D	01-JUN-87	02:02:47	770867	8.92	167	662.2	1.0	577.9	GL1

Table 4.2 (b) Complex Borehole History, HVB/52.7D

Activity Description			Start Date ddmmmyy	Start Time hh:mm:ss	Elapsed Time (s)	Elapsed Time (d)	Event Duration (s)	Measrd/ Estmt'd P (kPa)	Equiv. Fld Hght (arp) (m BRP)	Pressure Reading	Data Ref.
Packer Inflation (P3)	P3	OBS1/78.9D	01-JUN-87	04:21:30	779190	9.02	8323	757.0	1.4	581.2	GL1
Packer Deflation (P3)	P3	OBS1/78.9D	02-JUN-87	06:04:07	871747	10.09	92557	755.1	1.2	579.3	GL1
End Test	P3	OBS1/78.9D	02-JUN-87	06:10:00	872100	10.09	353	754.3	1.1	578.5	GL1
Start run-in	P2	OBS1/CASING	03-JUN-87	00:00:00	936300	10.84	64200	219.9	1.4	581.1	GL1
On depth	P2	OBS1/CASING	03-JUN-87	02:25:00	945000	10.94	8700	219.9	1.4	581.1	GL1
Start packer inflation	P1	OBS1/CASING	03-JUN-87	02:56:00	946860	10.96	1860	278.7	6.9	635.7	GL1
End packer inflation	P1	OBS1/CASING	03-JUN-87	03:30:00	948900	10.98	2040	250.7	4.1	607.7	GL1
Start Compliance period	P1	OBS1/CASING	03-JUN-87	03:30:00	948900	10.98	0	250.7	4.1	607.7	GL1
End Compliance period	P1	OBS1/CASING	03-JUN-87	04:27:37	952357	11.02	3457	224.1	1.4	581.1	GL1
Start Psr (Close SI - FAV)	P1	OBS1/CASING	03-JUN-87	04:27:37	952357	11.02	0	224.1	1.4	581.1	GL1
Psr	P1	OBS1/CASING	03-JUN-87	05:15:00	955200	11.06	2843	207.4	-0.3	564.4	GL1
Psr	P1	OBS1/CASING	03-JUN-87	06:15:00	958800	11.10	3600	192.4	-1.9	549.4	GL1
Psr	P1	OBS1/CASING	03-JUN-87	07:30:00	963300	11.15	4500	177.9	-3.3	534.9	GL1
End Psr	P1	OBS1/CASING	03-JUN-87	08:49:55	968095	11.20	4795	165.4	-4.6	522.4	GL1
Start Si1	P1	OBS1/CASING	03-JUN-87	08:49:55	968095	11.20	0	165.4	-4.6	522.4	GL1
End Si1	P1	OBS1/CASING	03-JUN-87	08:56:11	968471	11.21	376	164.6	-4.7	521.6	GL1
Start Pr1	P1	OBS1/CASING	03-JUN-87	08:56:11	968471	11.21	0	164.6	-4.7	521.6	GL1
Pr1	P1	OBS1/CASING	03-JUN-87	11:00:00	975900	11.30	7429	149.7	-6.2	506.7	GL1
Pr1	P1	OBS1/CASING	03-JUN-87	13:30:00	984900	11.40	9000	136.3	-7.6	493.3	GL1
End Pr1	P1	OBS1/CASING	03-JUN-87	15:04:28	990568	11.46	5668	131.7	-8.1	488.7	GL1
Start packer deflation	P1	OBS1/CASING	03-JUN-87	15:04:28	990568	11.46	0	131.7	-8.1	488.7	GL1
End Packer Deflation	P1	OBS1/CASING	03-JUN-87	15:04:31	990571	11.46	3	131.7	-8.1	488.7	GL1
End Test	P2	OBS1/CASING	03-JUN-87	15:15:27	991227	11.47	656	210.0	0.4	571.2	GL1
Start run-in	P2	OBS1/CASING	03-JUN-87	15:40:00	992700	11.49	1473	210.0	0.4	571.2	GL1
On depth	P2	OBS1/42.5D	03-JUN-87	16:30:00	995700	11.52	3000	479.2	1.2	579.2	GL1
Start packer inflation	P2	OBS1/42.5D	03-JUN-87	21:58:29	1015409	11.75	19709	478.0	1.1	578.0	GL1
Contd packer inflation	P1	OBS1/42.5D	03-JUN-87	22:02:33	1015653	11.76	244	575.4	10.5	670.8	GL1
End packer inflation	P1	OBS1/42.5D	03-JUN-87	23:00:17	1019117	11.80	3464	509.2	3.8	604.6	GL1
Start Compliance period	P1	OBS1/42.5D	03-JUN-87	23:00:17	1019117	11.80	0	509.2	3.8	604.6	GL1
End Compliance period	P1	OBS1/42.5D	03-JUN-87	23:39:00	1021440	11.82	2323	462.4	-1.0	557.8	GL1
Start Psr (Close SI - FAV)	P1	OBS1/42.5D	03-JUN-87	23:39:00	1021440	11.82	0	462.4	-1.0	557.8	GL1
Psr	P1	OBS1/42.5D	03-JUN-87	23:50:00	1022100	11.83	660	453.6	-1.9	549.0	GL1
Psr	P1	OBS1/42.5D	04-JUN-87	00:30:00	1024500	11.86	2400	428.3	-4.5	523.7	GL1
End Psr	P1	OBS1/42.5D	04-JUN-87	01:35:21	1028421	11.90	3921	399.7	-7.4	495.1	GL1
Start Pi1	P1	OBS1/42.5D	04-JUN-87	01:35:21	1028421	11.90	0	399.7	-7.4	495.1	GL1
Pi1	P1	OBS1/42.5D	04-JUN-87	01:45:04	1029004	11.91	583	396.3	-7.8	491.7	GL1
Pi1	P1	OBS1/42.5D	04-JUN-87	02:00:00	1029900	11.92	896	391.2	-8.3	486.6	GL1
Pi1	P1	OBS1/42.5D	04-JUN-87	02:55:00	1033200	11.96	3300	375.3	-9.9	470.7	GL1
Pi1	P1	OBS1/42.5D	04-JUN-87	04:00:00	1037100	12.00	3900	361.2	-11.3	456.6	GL1
Pi1	P1	OBS1/42.5D	04-JUN-87	05:00:00	1040700	12.05	3600	350.5	-12.4	445.9	GL1
End Pi1	P1	OBS1/42.5D	04-JUN-87	06:28:14	1045994	12.11	5294	337.1	-13.8	432.5	GL1
Start packer deflation	P1	OBS1/42.5D	04-JUN-87	06:28:14	1045994	12.11	0	337.1	-13.8	432.5	GL1
End Packer Deflation	P1	OBS1/42.5D	04-JUN-87	06:28:20	1046000	12.11	6	337.1	-13.8	432.5	GL1
End Test	P2	OBS1/42.5D	04-JUN-87	06:36:00	1046460	12.11	460	480.0	1.3	580.0	GL1
Start run-in	P2	OBS1/42.5D	04-JUN-87	07:15:00	1048800	12.14	2340	477.8	1.0	577.8	GL1
On depth	P2	OBS1/47.6D	04-JUN-87	07:42:00	1050420	12.16	1620	530.1	1.3	580.1	GL1
Start packer inflation	P2	OBS1/47.6D	04-JUN-87	07:46:44	1050704	12.16	284	530.1	1.3	580.1	GL1
End packer inflation	P2	OBS1/47.6D	04-JUN-87	08:04:00	1051740	12.17	1036	531.5	1.4	581.5	GL1
Start Compliance period	P1	OBS1/47.6D	04-JUN-87	08:04:00	1051740	12.17	0	615.6	9.5	661.0	GL1
End Compliance period	P1	OBS1/47.6D	04-JUN-87	08:34:00	1053540	12.19	1800	523.9	0.2	569.3	GL1
Start Psr (Close SI - FAV)	P1	OBS1/47.6D	04-JUN-87	08:34:00	1053540	12.19	0	523.9	0.2	569.3	GL1
Psr	P1	OBS1/47.6D	04-JUN-87	09:00:00	1055100	12.21	1560	486.8	-3.6	532.2	GL1
Psr	P1	OBS1/47.6D	04-JUN-87	09:30:00	1056900	12.23	1800	459.2	-6.4	504.6	GL1
Psr	P1	OBS1/47.6D	04-JUN-87	10:30:00	1060500	12.27	3600	427.4	-9.7	472.8	GL1
End Psr	P1	OBS1/47.6D	04-JUN-87	12:36:20	1068070	12.36	7570	390.8	-13.4	436.2	GL1
Start Pi1	P1	OBS1/47.6D	04-JUN-87	12:36:20	1068070	12.36	0	390.8	-13.4	436.2	GL1
End Pi1	P1	OBS1/47.6D	04-JUN-87	13:23:29	1070910	12.39	2840	383.1	-14.2	428.5	GL1
Start Pi2	P1	OBS1/47.6D	04-JUN-87	13:23:29	1070910	12.39	0	383.1	-14.2	428.5	GL1
Pi2	P1	OBS1/47.6D	04-JUN-87	14:00:00	1073100	12.42	2190	377.9	-14.7	423.3	GL1
Pi2	P1	OBS1/47.6D	04-JUN-87	16:30:00	1082100	12.52	9000	358.0	-16.8	403.4	GL1
Pi2	P1	OBS1/47.6D	04-JUN-87	19:00:00	1091100	12.63	9000	341.2	-18.5	386.6	GL1
Stop Pi2	P1	OBS1/47.6D	04-JUN-87	22:56:03	1105263	12.79	14163	320.4	-20.6	365.8	GL1
Start Pr1	P1	OBS1/47.6D	04-JUN-87	22:56:03	1105263	12.79	0	320.4	-20.6	365.8	GL1
Pr1	P1	OBS1/47.6D	05-JUN-87	01:30:00	1114500	12.90	9237	308.4	-21.8	353.8	GL1
Stop Pr1	P1	OBS1/47.6D	05-JUN-87	03:46:30	1122660	12.99	8160	299.2	-22.8	344.6	GL1
Start Q1-1	P1	OBS1/47.6D	05-JUN-87	03:46:30	1122660	12.99	0	299.2	-22.8	344.6	GL1
Stop Q1-1	P1	OBS1/47.6D	05-JUN-87	06:14:21	1131541	13.10	8881	290.2	-23.7	335.6	GL1

Table 4.2 (b) Complex Borehole History,HVB/52.7D

Activity Description			Start Date ddmmmyy	Start Time hh:mm:ss	Elapsed Time (s)	Elapsed Time (d)	Event Duration (s)	Measrd/ Estmt'd P (kPa)	Equiv. Fld Hght (arp) (m BRP)	Pressure Reading	Data Ref.
Start Q1-2	P1	OBS1/47.6D	05-JUN-87	06:14:21	1131541	13.10	0	290.2	-23.7	335.6	GL1
Stop Q1-2	P1	OBS1/47.6D	05-JUN-87	08:21:47	1139159	13.18	7618	283.9	-24.3	329.3	GL1
Start Pr2	P1	OBS1/47.6D	05-JUN-87	08:21:47	1139159	13.18	0	283.9	-24.3	329.3	GL1
Pr2	P1	OBS1/47.6D	05-JUN-87	10:00:00	1145100	13.25	5941	278.1	-24.9	323.5	GL1
Stop Pr2	P1	OBS1/47.6D	05-JUN-87	13:10:30	1156530	13.39	11430	268.7	-25.9	314.1	GL1
Start packer deflation	P1	OBS1/47.6D	05-JUN-87	13:10:30	1156530	13.39	0	268.7	-25.9	314.1	GL1
End Packer Deflation	P1	OBS1/47.6D	05-JUN-87	13:11:00	1156560	13.39	30	268.7	-25.9	314.1	GL1
End Test	P2	OBS1/47.6D	05-JUN-87	13:15:00	1156800	13.39	240	526.6	0.9	576.6	GL1
Start run-in	P2	OBS1/47.6D	05-JUN-87	13:15:00	1156800	13.39	0	526.6	0.9	576.6	GL1
On depth	P2	OBS1/52.7D	05-JUN-87	14:00:00	1159500	13.42	2700	578.5	1.1	578.5	GL1
Start packer inflation	P2	OBS1/52.7D	05-JUN-87	14:14:49	1160389	13.43	889	578.7	1.1	578.7	GL1
End packer inflation	P2	OBS1/52.7D	05-JUN-87	14:19:30	1160670	13.43	281	592.8	2.6	592.8	GL1
Start Compliance period	P2	OBS1/52.7D	05-JUN-87	14:19:30	1160670	13.43	0	592.8	2.6	592.8	GL1

DATA REFERENCES
Gc1 Gemag - drilling logs
Gc2 Gemag - field notes
GL1 - field notes

Table 5.1: Casing Test 2 Activity Log

DATE	TIME	EVENT	ACTIVITY DESCRIPTION
16 JN	16:30		Fill casing with water, run-in packers and tool (P1 valve closed)
Part 1	(see Figures 5.10, 5.11)		
16 JN	17:35	Fig 5.10, A-B	Inflate packers (65 bar)
16 JN	17:50	Fig 5.10, C	Close packer inflate line
16 JN	18:26		Close FAV, recovery over night
17 JN	10:28	Fig 5.11, A-D	Inject water into interval (P = 5.8 bar injected volume unkown)
17 JN	11:02	Fig 5.11, E-F	Apply pressure pulse at P2 valve (dP = 5.2 bar)
17 JN	11:30	Fig 5.11, G-H	Open P2 valve, remove 56 ml (dP = -520 kPa)
17 JN	12:00		Open FAV
Part 2	(see Figure 5.12)		
17 JN	12:05	Fig 5.12, A	Re-inflate packers with 65 bar constant pressure source
17 JN	14:22		Close FAV Open P1 valve for a second
17 JN	14:45	Fig 5.12, B-C	V = 54 ml. dP = 34.2 bar
17 JN	14:55	Fig 5.12, H-I	Stepwise injection of water into interval
17 JN	17:10	Fig 5.12, E-F	Open P1 valve
17 JN	17:10	Fig 5.12, J-K	Open P2 valve, 66 ml water recovered

Table 5.2 Effective Radius Calculations from Casing Test

Event	Interval	Volume (L)	Field Re (mm)	Theor. Re (mm)	Sc (m^2)	Effective Vol. (L)
1	P2	21.5	0.58	0.17	9.64E-07	244.8
2	P1	7.0	0.22	0.10	1.22E-07	35.2
3	P2	21.5	0.46	0.17	5.72E-07	154.0
4	P2	21.5	0.41	0.17	4.35E-07	122.3

Sc = System Compliance

Table 5.3 Comparison of Compliance Responses for the P1 and P2 Intervals

Event	Start Pres. P2 (kPa)	End Pres. P2 (kPa)	delta P2 (kPa)	Start Pres. P1 (kPa)	End Pres. P1 (kPa)	delta P1 (kPa)
Step 1	131.5	130.7	-0.8	594.5	597.5	3.0
Step 2	191.7	190.1	-1.6	598.0	598.7	0.7
Step 3	345.2	341.4	-3.8	599.6	600.1	0.5
Step 4	595.5	585.9	-9.6	608.2	609.0	0.8
Step 5	803.4	787.6	-15.8	621.1	622.4	1.3
Step 6	1095.2	1078.2	-17.0	625.8	626.8	1.0
Step 7	1408.7	1309.7	-99.0	629.4	635.8	6.4

Event	Pres. Incr. P1 (kPa)	Pres. Incr. P2 (kPa)	Vol. Inject P2 (L)	Cum Vol (L)
Step 0-1	0.4	35.2	17.2	17.2
Step 1-2	0.5	61.0	16.2	33.4
Step 2-3	0.9	155.1	18.1	51.5
Step 3-4	8.1	254.1	13.6	65.1
Step 4-5	12.1	217.5	7.8	72.9
Step 5-6	3.4	307.6	8.0	80.9
Step 6-7	2.6	330.5	7.3	88.2

TABLE 6.1: TESTING EVENT SUMMARY HVB/48.6D

EVENT	INF	COM	Psr	Pil	Sil	Pr1	Sw1	Pr2	Def
START DATE	29-MAY-87	29-MAY-87	29-MAY-87	29-MAY-87	29-MAY-87	29-MAY-87	30-MAY-87	30-MAY-87	30-MAY-87
START TIME	07:49:00	07:52:00	10:03:27	11:10:27	11:35:51	11:48:53	15:03:05	16:14:46	19:54:00
END DATE	29-MAY-87	29-MAY-87	29-MAY-87	29-MAY-87	29-MAY-87	30-MAY-87	30-MAY-87	30-MAY-87	
END TIME	07:52:00	10:03:27	11:10:27	11:35:51	11:48:53	15:03:05	16:14:46	19:54:00	
delta t (s)	180.0	7887.0	4020.0	1524.0	782.0	98052.0	4301.0	13154.0	
delta t (m)	3.0	131.4	67.0	25.4	13.0	1634.2	71.7	219.2	
SIV (L)			111.0	111.0		111.0		111.0	
Re (mm-est.)		21.0	0.4	0.4	21.0	0.4	21.0	0.4	
PRESSURES (kPa)									
P2 start	460.2	474.0	472.7	470.2	470.5	470.1	166.0	168.1	213.0
P2 end	474.0	472.7	377.2	380.0	470.1	251.2	168.1	213.0	454.7
delta P2	13.8	-1.3	-95.5	-90.2	-0.4	-218.9	2.1	44.9	241.7
P1 start	484.3	552.2	337.0	293.9	279.6	272.9	321.3	313.5	294.4
P1 end	552.2	337.0	293.9	279.6	272.9	321.3	313.5	294.4	502.7
delta P1	67.9	-215.2	-43.1	-14.3	-6.6	48.4	-7.8	-19.1	208.3
P3 start	457.6	458.0	458.2	458.1	458.1	458.0	455.5	455.7	455.7
P3 end	458.0	458.2	458.1	458.1	458.0	455.5	455.7	455.7	452.7
delta P3	0.4	0.1	-0.1	-0.0	-0.1	-2.5	0.2	0.0	-2.9
PS start	98	6325	5368	5238	5213	5200	4454	4435	4384
PS end	6325	5368	5238	5213	5200	4454	4435	4384	85
delta PS	6227	-957	-131	-25	-13	-745	-19	-51	-4299
TEMPERATURES (deg C)						C)			
T2 start	15.1	15.2	16.1	16.7	16.8	16.8	16.6	16.5	16.5
T2 end	15.2	16.1	16.7	16.8	16.8	16.6	16.5	16.5	16.8
delta T2	0.1	0.9	0.6	0.1	0.0	-0.2	-0.1	0.0	0.2
T1 start	15.3	15.3	16.3	16.5	16.6	16.6	16.7	16.8	16.8
T1 end	15.3	16.3	16.5	16.6	16.6	16.7	16.8	16.8	16.7
delta T2	0.1	0.9	0.3	0.0	0.0	0.1	0.1	-0.0	-0.1
T3 start	14.6	14.6	15.6	15.7	15.8	15.8	16.5	16.5	16.5
T3 end	14.6	15.6	15.7	15.8	15.8	16.5	16.5	16.5	16.5
delta T3	0.1	0.9	0.2	0.1	0.0	0.7	0.0	-0.0	-0.1
TS start	19.6	19.6	19.6	19.6	19.6	19.6	19.7	19.7	19.6
TS end	19.6	19.6	19.6	19.6	19.6	19.7	19.7	19.6	19.6
delta TS	0.0	-0.0	0.0	0.0	0.0	0.1	0.0	-0.1	0.0

TABLE 6.2: TESTING EVENT SUMMARY HGB/55.5D1

EVENT	INF	COM	Psr	Pi1	Pi2	Pr1	Si1	Pr2	Sw1	Pr3
START DATE	28-JUN-87	28-JUN-87	28-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87
START TIME	17:41:30	17:46:30	18:51:30	01:27:22	02:43:24	03:03:24	04:45:44	06:55:43	09:10:54	11:10:58
END DATE	28-JUN-87	28-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87	29-JUN-87
END TIME	17:46:30	18:51:30	01:27:22	02:43:24	03:03:24	04:45:44	06:55:43	09:10:54	11:10:58	13:26:31
delta t (s)	300	3900	23752	4562	1200	6140	7799	8111	7204	8133
delta t (m)	5.0	65.0	395.9	76.0	20.0	102.3	130.0	135.2	120.1	135.5
SIV (L)			50	50	896	50		50		50
Re (mm-est.)		21	0.3	0.3	1	0.3	21	0.3	21	0.3
PRESSURES (kPa)										
P2 start	462.2	468.9	469.0	874.5	859.0	396.0	469.9	424.5	143.7	170.4
P2 end	468.9	469.0	308.9	245.8	396.0	252.1	424.5	274.2	170.4	239.9
delta P2	6.7	0.1	-160.1	-628.7	-463.0	-143.9	-45.4	-150.3	26.7	69.5
P1 start	468.8	476.7	203.4	135.8	134.5	133.2	125.4	122.8	121.5	120.2
P1 end	476.7	203.4	135.8	134.5	133.2	125.4	122.8	121.5	120.2	119.4
delta P1	7.8	-273.3	-67.6	-1.3	-1.3	-7.8	-2.6	-1.3	-1.3	-0.8
P3 start	462.5	465.4	466.5	466.5	466.2	466.1	466.2	466.5	466.5	466.6
P3 end	465.4	466.5	466.5	466.2	466.1	466.2	466.5	466.5	466.6	465.4
delta P3	2.9	1.1	0.0	-0.3	-0.1	0.1	0.3	0.0	0.1	-1.2
PS start	158	5189	5121	5111	5108	5108	5105	5101	5098	5094
PS end	5189	5121	5111	5108	5108	5105	5101	5098	5094	5091
delta PS	5031	-68	-10	-3	0	-3	-4	-3	-4	-3
TEMPERATURES (deg C)										
T2 start	16.8	16.8	16.8	16.3	16.4	16.7	16.8	16.7	16.5	16.5
T2 end	16.8	16.8	16.6	16.6	16.7	16.8	16.8	16.6	16.5	16.6
delta T2	0.0	0.0	-0.2	0.3	0.3	0.1	0.0	-0.1	0.0	0.1
T1 start	16.6	16.6	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5
T1 end	16.6	16.5	16.7	16.6	16.5	16.5	16.5	16.5	16.5	16.6
delta T2	0.0	-0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1
T3 start	15.9	15.9	15.9	15.8	15.9	16.0	15.9	15.9	15.9	15.8
T3 end	15.9	15.9	15.8	15.9	16.0	15.9	16.0	15.9	15.8	15.9
delta T3	0.0	0.0	-0.1	0.1	0.1	-0.1	0.1	0.0	-0.1	0.1
TS start	20.2	20.3	19.6	20.3	20.3	20.3	20.3	20.3	20.3	20.3
TS end	20.3	19.6	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
delta TS	0.1	-0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 6.3: TESTING EVENT SUMMARY SA/311.OD

EVENT	INF	COM	Psr	Pil	Sw1	Pr1	DEF
START DATE	09-AUG-87	09-AUG-87	09-AUG-87	09-AUG-87	09-AUG-87	09-AUG-87	10-AUG-87
START TIME	09:50:00	10:00:40	11:09:52	16:02:30	17:27:24	21:37:30	10:43:00
END DATE	09-AUG-87	09-AUG-87	09-AUG-87	09-AUG-87	09-AUG-87	10-AUG-87	10-AUG-87
END TIME	10:00:40	11:09:52	16:02:30	17:27:24	21:37:30	10:43:00	10:51:00
delta t (s)	640	4152	17558	5094	15006	47130	480
delta t (m)	10.7	69.2	292.6	84.9	250.1	785.5	8.0
SIV (L)			83.00	83.00		83.00	
Re (mm-est.)		20.96	0.34	0.34	20.96	0.34	
PRESSURES (kPa)							
P2 start	3027.7	3036.4	2997.5	3843.0	2233.0	2356.7	2505.0
P2 end	3036.4	2997.5	2519.4	2523.9	2356.7	2505.0	2855.5
delta P2	8.7	-38.8	-478.1	-1319.1	123.7	148.3	350.5
P1 start	3030.38	3214.63	3044.14	2887.11	2871.15	2847.23	2823.0
P1 end	3214.63	3044.14	2887.11	2871.15	2847.23	2823.03	2870.49
delta P1	184.25	-170.49	-157.03	-15.96	-23.92	-24.20	47.46
P3 start	3023.94	3026.00	3021.07	3005.36	3001.42	2989.60	2947.4
P3 end	3026.00	3021.07	3005.36	3001.42	2989.60	2947.43	2864.40
delta P3	2.06	-4.93	-15.71	-3.94	-11.82	-42.17	-83.03
PS start	600	5517	5723	5870	5883	5910	5945
PS end	5517	5723	5870	5883	5910	5945	95
delta PS	4918	206	146	13	27	36	-5850
TEMPERATURES (deg C)							
T2 start	23.37	23.38	23.40	23.50	23.52	23.53	23.58
T2 end	23.38	23.40	23.50	23.52	23.53	23.58	23.54
delta T2	0.01	0.02	0.10	0.02	0.01	0.05	-0.04
T1 start	23.72	23.80	23.86	23.74	23.72	23.71	23.69
T1 end	23.80	23.86	23.74	23.72	23.71	23.69	23.72
delta T2	0.08	0.06	-0.12	-0.02	-0.01	-0.02	0.03
T3 start	22.87	22.88	22.88	22.86	22.86	22.87	22.98
T3 end	22.88	22.88	22.86	22.86	22.87	22.98	22.99
delta T3	0.01	0.00	-0.02	0.00	0.01	0.11	0.01
TS start	20.85	21.12	21.66	21.70	21.74	21.70	21.62
TS end	21.12	21.66	21.70	21.74	21.70	21.62	21.63
delta TS	0.27	0.54	0.04	0.04	-0.04	-0.08	0.01

Table 7.1 HVB Planned and Actual Testing Intervals

Screening Tests:

	Planned Interval	Actual Interval	Test ID	App. #
1	20 - 40	18.5 - 38.6	28.6D	A2
2	40 - 60	38.5 - 58.6	48.6D	A6
3	60 - 80	59.6 - 79.6	69.6D	A8
4	80 - 100	68.9 - 88.9	78.9D	A10

Detailed Tests:

	Planned Interval	Actual Interval	Test ID	App. #
1	40 - 45	40.0 - 45.1	42.5D	A4
2	45 - 50	45.1 - 50.1	47.6D	A5
3	50 - 55	50.1 - 55.2	52.7D	A7
4	55 - 60	cancelled	-	-
5	60 - 65	cancelled	-	-
6	40 - 60	cancelled	-	-
-	additional	23.1 - 28.1	25.6D	A1
-	additional	28.9 - 35.0	32.0D	A3
-	additional	72.0 - 77.1	74.5D	A9

TABLE 7.2: Summary of Hydrogeologic Results for the Oberbauenstock HVB 100m Vertical Borehole

BOREHOLE INTERVAL	APNDX NO.	TOP PACKER DEPTH [m brp]	BOTTOM PACKER DEPTH [m brp]	INTERVAL LENGTH [m]	INTERVAL MIDPOINT PRESSURE [kPa] P	HEAD AT MIDPOINT [masl]	P1 PRESSURE (est.) [kPa]	HYDRAULIC CONDUCTIVITY [m/s] K	CONTR. ZONE LENGTH [m] L	TRANSMISSIVITY [m^2/s] T	STORATIVITY [dim] S	SPECIFIC STORAGE [m-1] Ss	TEMPERATURE [deg C]
25.6D	A-1	23.1	28.1	5.06	150 to 250	472 to 482	157	<2E-12	5.06	<1E-11	5E-07 to 5E-04	1E-07 to 1E-04	16
28.6D	A-2	18.5	38.6	20.03	250	479	83	<1E-11	18.27	<2E-10	1E-06 to 1E-03	5E-08 to 5E-05	17
32.0D	A-3	28.9	35.0	6.06	200 to 300	471 to 482	176	<2E-12	6.06	<1E-11	5E-07 to 5E-04	8E-08 to 8E-05	17
42.5D	A-4	40.0	45.1	5.06	200 to 450	460 to 486	337	<1E-13	5.06	<5E-13	5E-07 to 5E-04	1E-07 to 1E-04	17
47.6D	A-5	45.1	50.1	5.06	200 to 450	455 to 481	269	3E-12 to 1E-10	5.06	2E-11 to 5E-10	5E-07 to 5E-04	1E-07 to 1E-04	17
48.6D	A-6	38.5	58.6	20.03	255 to 340	460 to 469	110	1E-12 to 2E-11	20.03	2E-11 to 4E-10	1E-03 to 1E-05	5E-05 to 5E-07	17
52.7D	A-7	50.1	55.2	5.06	200 to 500	450 to 481	292	<1E-12	5.06	<5E-12	5E-07 to 5E-04	1E-07 to 1E-04	17
69.6D	A-8	59.6	79.6	20.03	273 to 378	441 to 452	247	<1E-09	20.03	<2E-08	3E-06 to 1E-03	1E-07 to 5E-05	17
74.5D	A-9	72.0	77.1	5.06	300 to 450	439 to 454	525	<1E-12	5.06	<5E-12	1E-07 to 1E-03	2E-08 to 2E-04	17
78.9D	A-10	68.9	88.9	20.03	323 to 423	437 to 447	411	<5E-12	20.03	<1E-10	1E-06 to 1E-03	5E-08 to 5E-05	17

Table 7.3: HVB GLIMPSE Simulation Static Pressures

Test	P2 Static Pressure Range (kPa) (1)	P2 Static Centre Value (kPa) (2)	P2 Hydraulic Head (masl) (3)
25.6D	100 - 200	150	472-482
28.6D	75 - 125	100	476-479
32.0D	150 - 250	250	471-482
42.5D	150 - 400	150	460-486
47.6D	150 - 400	150	455-481
48.6D	130 - 215	215	460-469
52.7D	150 - 450	150	450-481
69.6D	150 - 255	200	441-452
74.5D	250 - 400	250	439-454
78.9D	200 - 350	200	437-452

Footnotes: (1) Range in P2 static pressures used in the GLIMPSE simulation
(2) Best estimate of P2 static value
(3) Assumptions: $g = 9.81$ m/s, $\rho = 1000$ kg/m^3, Ref. Pt. = 492.4 masl

Table 7.4: HVB Bottomhole Pressure Values

Test	P1 End Pressure (kPa) (4)	P1 Hydraulic Head (masl) (3)	P1 Transducer Depth (mbrp)	P1 Bottomhole Zone (mbrp)
25.6D	<<157	<<478	20.9	29.0-100.2
28.6D	<<83	<<475	16.3	39.5-100.2
32.0D	<176	<474	26.7	35.8-100.2
42.5D	<337	<480	37.8	45.9-100.2
47.6D	<269	<468	42.9	51.0-100.2
48.6D	<110	<458	36.3	59.4-100.2
52.7D	<292	<465	47.9	56.1-100.2
69.6D	<<247	<<451	57.4	80.5-100.2
74.5D	<525	<467	69.8	77.9-100.2
78.9D	<411	<458	66.7	89.8-100.2

Footnotes: (3) Assumptions: $g = 9.81$ m/s, $\rho = 1000$ kg/m^3, Ref. Pt. = 492.4 masl
(4) < = P1 pressure dropping at end of test; reported value is a maximum
<< = P1 response levelled out, possible vapour pressure affecting results

Table 8.1: HGB Planned and Actual Testing Intervals

Screening Tests:

	Planned Interval	Actual Interval	Test ID	App. #
1	73.0 - 92.0	73.0 - 92.0	82.5D	B11
2	53.0 - 72.0	53.0 - 72.0	62.5D	B8
3	33.0 - 52.0	33.0 - 52.0	42.5D	B3
4	13.0 - 32.0	-	-	

Detailed Tests:

	Planned Interval	Actual Interval	Test ID	App. #
1	73.0 - 79.5	73.0 - 79.6	76.3D	B10
2	80.0 - 86.5	80.0 - 86.6	83.3D	B12
3	86.0 - 92.5	-	-	
4	65.5 - 72.0	65.4 - 72.0	68.7D	B9
5	59.5 - 66.0	58.8 - 65.4	62.1D	B7
6	53.5 - 60.0(1)	52.2 - 58.8	55.5D1	B4
7	26.5 - 33.0	26.4 - 33.0	29.7D	B2
8	19.0 - 25.5	19.8 - 26.4	23.1D	B1
9	53.5 - 60.0(2)	52.2 - 58.8	55.5D2	B5
10	53.5 - 60.0(G)	52.2 - 58.8	55.5Dgas	B6

TABLE 8.2: Summary of Hydrogeologic Results for the Oberbauenstock HGB 100m Inclined Borehole

BOREHOLE INTERVAL	APNDX NO.	TOP PACKER DEPTH [m brp] (drilled) (true)	BOTTOM PACKER DEPTH [m brp] (drilled) (true)	INTERVAL LENGTH [m]	INTERVAL MIDPOINT PRESSURE [kPa] P	HEAD AT MIDPOINT [masl]	P1 PRESSURE (est.) [kPa]	HYDRAULIC CONDUCTIVITY [m/s] K	CONTR. ZONE LENGTH [m] L	TRANSMISSIVITY [m^2/s] T	STORATIVITY [dim] S	SPECIFIC STORAGE [1/m] Ss	TEMPERATURE [deg C]
23.1D	B-1	19.8 14.6	26.4 19.4	6.58	136	480	74	5E-13 to 1E-12	6.32	3E-12 to 6E-12	1E-06 to 1E-04	2E-07 to 2E-05	17
29.7D	B-2	26.4 19.5	33.0 24.2	6.58	136 to 166	475 to 478	59	1E-13 to 1E-12	6.58	7E-13 to 7E-12	1E-06 to 1E-04	2E-07 to 2E-05	16
42.5D	B-3	33.0 24.2	52.1 38.4	19.05	182	470	73	1E-12 to 5E-12	19.05	2E-11 to 1E-10	1E-06 to 1E-03	5E-08 to 5E-05	17
55.5D1	B-4	52.2 38.6	58.8 43.5	6.58	190 to 290	462 to 472	120	1E-09 to 1E-08	6.58	7E-09 to 7E-08	1E-05 to 1E-03	2E-06 to 2E-04	17
55.5D2	B-5	52.2 38.6	58.8 43.5	6.58	262	469	-	1E-09 to 1E-08	6.58	7E-09 to 7E-08	1E-05 to 1E-03	2E-06 to 2E-04	17
55.5DG	B-6	52.2 38.6	58.8 43.5	6.58	N/D	N/D	N/D	9E-10 3E-09	6.58	6E-09 to 2E-08	N/D	N/D	17
62.1D	B-7	58.8 43.5	65.4 48.4	6.58	217 to 317	459 to 470	163	1E-11 to 5E-11	6.58	7E-11 to 3E-10	1E-03 to 1E-06	2E-04 to 2E-07	17
62.5D	B-8	53.0 39.1	72.1 53.5	19.05	308	468	127	1E-09 to 1E-08	19.05	2E-08 to 2E-07	1E-05 to 1E-03	5E-07 to 5E-05	17
68.7D	B-9	65.4 48.4	72.0 53.4	6.58	292 to 342	462 to 467	197	1E-12 to 1E-10	6.58	7E-12 to 7E-10	1E-07 to 1E-03	2E-08 to 2E-04	17
76.3D	B-10	73.0 54.2	79.6 59.2	6.58	283 to 383	455 to 465	351	2E-13 to 2E-12	6.58	1E-12 to 1E-11	1E-06 to 1E-03	2E-07 to 2E-04	17
82.5D	B-11	73.0 54.2	92.1 68.7	19.05	300 to 350	455 to 457	517	1E-09 to 1E-08	19.05	2E-08 to 2E-07	1E-05 to 1E-03	5E-07 to 5E-05	17
83.3D	B-12	80.0 59.5	86.6 64.5	6.58	393	462	252	1E-08 to 5E-09	6.58	7E-08 to 3E-08	1E-06 to 1E-04	2E-07 to 2E-05	17

Table 8.3: HGB GLIMPSE Simulation Static Pressures

Test	P2 Static Pressure Range (kPa) (1)	P2 Static Centre Value (kPa) (2)	P2 Hydraulic Head (masl) (3)
23.1D	95	95	480
29.7D	95 - 125	95	475 - 478
42.5D	95	95	470
55.5D-1	150 - 250	150	462 - 472
55.5D-2	-	220	469
55.5D-GT	-	-	-
62.1D	175 - 275	275	459 - 470
62.5D	220	220	468
68.7D	250 - 300	250	462 - 467
76.3D	240 - 340	290	455 - 465
82.5D	200 - 300	250	451 - 461
83.3D	300 - 390	350	456 - 465

Footnotes: (1) Range in P2 static pressures used in the GLIMPSE simulations
(2) Best estimate of P2 static value
(3) Assumptions: $g = 9.81$ m/s, $\rho = 1000$ kg/m^3, Ref. Pt. = 492.8 masl

Table 8.4: HGB Bottomhole Pressure Values

Test	P1 End Pressure (kPa) (4)	P1 Hydraulic Head (masl) (3)	P1 Transducer Level (true) (mbrp)	P1 Interval (m)
23.1D	74*	478	12.9	27.3-100.8
29.7D	59*	472	17.8	33.9-100.8
42.5D	73*	468	22.6	52.9-100.8
55.5D-1	120*	459	36.9	59.7-100.8
55.5D-2	-	-	-	-
55.5D-GT	-	-	-	-
62.1D	163*	458	41.8	66.3-100.8
62.5D	127*	459	37.5	72.9-100.8
68.7D	197*	457	46.8	72.9-100.8
76.3D	351*	467	52.5	80.5-100.8
82.5D	517*	484	52.5	92.9-100.8
83.3D	252*	451	57.8	87.5-100.8

Footnotes: (3) Assumptions: $g = 9.81$ m/s, $\rho = 1000$ kg/m^3, Ref. Pt. = 492.8 masl
(4) * = P1 surface valve open for part or all of test

Table 9.1: SA Borehole Activity Detail

DATE	ACTIVITY DESCRIPTION
July 7 - July 14	Drilling to 103.1 m
July 14 - July 16	Borehole preparation and geophysical logging
July 16 - July 19	Testing and sampling 100.2S
July 19 - July 22	Drilling from 103.1 to 165.9 m
July 22 - July 24	Testing 160.6S
July 24 - Aug 1	Drilling from 165.8 to 302.2 m
Aug 1 - Aug 3	Borehole preparation and geophysical logging
Aug 3 - Aug 5	Drilling from 302.2 to 348.5 m (TD)
Aug 5 - Aug 7	Borehole preparation and geophysical logging
Aug 7 - Aug 9	Testing 298.0D
Aug 9 - Aug 10	Testing 311.0D
Aug 10 - Aug 13	Run-out tool and install temporary casing. Increase straddle from 15 to 19 m
Aug 13 - Aug 16	Testing 196.5D1
Aug 16 - Aug 16	Run-out to replace FAV cable
Aug 16 - Aug 17	Testing 137.0D
Aug 17 - Aug 18	Testing 196.5D2
Aug 18 - Aug 23	Testing 157.0D

Table 9.2: Flow Checks and Fluid Losses During Drilling of the SA Borehole (1)

DATE	TIME	DEPTH RANGE (M)	ACTIVITY	LOSS RATE
July 7	-	30	Loss during drilling	0.004 l/min
July 12	-	50	Loss during drilling	0.018 l/min
July 13	-	76	Loss during drilling	0.096 l/min
July 14	20:38	99.2 - 101.7	Loss during drilling	600 l
July 14	22:36	101.7	Flow check	2.8 l/min
July 15	00:15	103.1	Flow check	2.0 l/min
July 20	17:23	120.6	Flow check	0.11 l/min
July 21	04:20	132.6	Flow check	+0.01 l/min
July 22	10:30	157.5 - 160.2	Flow check	15 l/min
July 22	13:00	160.2 - 163.1	Flow check	8 l/min
July 22	18:00	163.1 - 165.9	Flow check	7 l/min
July 22	18:41	165.9	Flow check	5 l/min
July 22	21:12	165.9	Flow check	0.7 l/min
July 26	19:45	174.2 - 182.7	Loss during drilling	0.44 l/min
July 27	06:00	182.7 - 205.4	Loss during drilling	1.0 l/min
July 27	09:08	188.0	Flow check	1.12 l/min
July 27	14:52	193.6	Flow check	1.53 l/min
July 27	21:00	196.3 - 199.3	Loss during drilling	2.9 l/min
July 28	00:21	199.3	Flow check	0.38 l/min
July 28	04:30	202.3 - 205.4	Loss during drilling	1.8 l/min
July 28	06:00	205.4	Flow check	2.3 l/min
July 28	06:13	205.4 - 229.9	Loss during drilling	1.1 l/min
July 28	11:54	211.0	Flow check	0.84 l/min
July 28	17:00	216.3 - 219.4	Loss during drilling	1.2 l/min
July 28	19:51	219.4	Flow check	0.49 l/min
July 29	06:00	230.2 - 252.9	Loss during drilling	0.5 l/min
July 29	13:49	238.6	Flow check	0.8 l/min
July 29	22:15	244.7 - 247.5		0.16 l/min
July 30	01:30	247.5 - 250.3	Loss during drilling	0.9 l/min
July 30	04:15	250.3 - 252.9	Loss during drilling	0.46 l/min
July 30	09:34	238.6	Flow check	0.74 l/min
July 30	16:40	263.7 - 266.6	Loss during drilling	5.0 l/min
July 30	19:10	266.5	Flow check	0.97 l/min
July 30	21:56	269.3	Flow check	0.19 l/min
July 31	03:00	272.1	Flow check	0.1 l/min
July 31	04:00	272.1 - 292.4	Loss during drilling	0.3 l/min
August 1	10:28	269.8	Flow check	0.14 l/min
August 1	12:53	297.6	Flow check	0.99 l/min
August 1	16:14	300.2	Flow check	0.60 l/min
August 2	13:30	300.2	Flow check	0.42 l/min

(1) Compiled from NIB 88-25

Table 9.3 : SA Borehole Packer Seats

Testing During Drilling:

	Planned Interval	Actual Interval	Test ID	App. #
1	100 m	97.2 - 102.1	100.2S	C1
2	-	156.0 - 165.8	160.6S	C4
3	250 m	-	-	

Testing After Drilling:

	Planned Interval	Actual Interval	Test ID	App. #
1	318.5 - 333.5	-	-	
2	303.5 - 318.5	303.5 - 318.5	311.0D	C8
3	290.0 - 305.0	290.5 - 305.5	298.0D	C7
4	274.0 - 289.0	-	-	
5	187.0 - 206.0	187.0 - 206.0	196.5D1	C5
6	-	187.0 - 206.0	196.5D2	C6
7	127.0 - 146.0	127.0 - 146.0	137.0D	C2
8	147.0 - 166.0	147.0 - 166.0	157.0D	C3

TABLE 9.4: Summary of Hydrogeologic Results for the Oberbauenstock SA 348m Vertical Borehole

BOREHOLE INTERVAL	APNDX NO.	TOP PACKER DEPTH [m brp]	BOTTOM PACKER DEPTH [m brp]	INTERVAL LENGTH [m]	INTERVAL MIDPOINT PRESSURE [kPa] P	HEAD [masl]	P1 PRESSURE (est.) [kPa]	HYDRAULIC CONDUCTIVITY [m/s] K	CONTR. ZONE LENGTH [m] L	TRANSMISSIVITY [m^2/s] T	STORATIVITY [dim] S	SPECIFIC STORAGE [1/m] Ss	TEMPERATURE [deg C]
100.2S	C-1	97.20	N/A	5.90	515	435	-	1E-07	5.90	6E-07	1E-05 to 1E-03	2E-06 to 2E-04	18
137.0D	C-2	127.50	146.58	19.08	270 to 470	373 to 393	814	1E-11 to 1E-09	19.08	2E-10 to 2E-08	1E-06 to 1E-04	5E-08 to 5E-06	19
157.0D	C-3	147.50	166.58	19.08	370 to 520	363 to 378	996	1E-09 to 1E-08	19.08	2E-08 to 2E-07	1E-07 to 1E-03	5E-09 to 5E-05	20
160.0S	C-4	156.00	N/A	9.80	320 to 360	355 to 359	-	1E-08 to 2E-08	9.80	1E-07 to 2E-07	1E-06 to 1E-03	1E-07 to 1E-04	20
196.5D1	C-5	187.00	206.08	19.08	570 to 670	344 to 354	1416	N/D	19.08	N/D	N/D	N/D	21
196.5D2	C-6	187.00	206.08	19.08	570 to 670	344 to 354	1392	5E-11 to 5E-10	19.08	1E-09 to 1E-08	1E-07 to 1E-03	5E-09 to 5E-05	20
298.0D	C-7	290.50	305.58	15.08	2480 to 3060	437 to 486	2399	1E-12 to 1E-11	15.08	2E-11 to 2E-10	1E-07 to 1E-03	7E-09 to 7E-05	23
311.0D	C-8	303.50	318.58	15.08	2550	431	2823	1E-09 to 5E-09	15.08	2E-08 to 8E-08	1E-07 to 1E-03	7E-09 to 7E-05	24

Table 9.5: SA GLIMPSE Simulation Static Pressures

Test	P2 Static Pressure Range (kPa) (1)	P2 Static Centre Value (kPa) (2)	P2 Hydraulic Head (masl) (3)
100.2S	435 - 485	460	435
137.0D	150 - 350	150	373 - 393
157.0D	250 - 400	-	363 - 378
160.0S	250 - 290	-	355 - 359
196.5D-1	440 - 540 (4)	-	344 - 354
196.5D-2	450 - 550	-	344 - 354
289.0D	2380 - 2960	-	437 - 497
311.0D	2400 - 2505	2450	426 - 436

Footnotes:
(1) Range in P2 static pressures used in the GLIMPSE simulations
(2) Best estimate of P2 static value
(3) Assumptions: $g = 9.81$ m/s, $\rho = 1000$ kg/m^3, Ref. Pt. = 492.3 masl
(4) Value obtained from Horner extrapolations; no GLIMPSE runs performed

Table 9.6: SA Bottomhole Pressure Values

Test	P1 End Pressure (kPa)	P1 Hydraulic Head (masl) (3)	P1 Transducer Level (true) (mbrp)	P1 Interval (m)
100.2S	-	-	-	-
137.0D	814	441	125.3	147.5-348.5
157.0D	996	439	145.3	167.5-348.5
160.0S	-	-	-	-
196.5D-1	1416	443	184.8	207.0-348.5
196.5D-2	1392	440	184.8	207.0-348.5
289.0D	2399	439	288.3	306.5-348.5
311.0D	2823	470	301.3	319.5-348.5

Footnotes: (3) Assumptions: $g = 9.81$ m/s, $\rho = 1000$ kg/m^3 Ref. Pt. = 492.3 masl

APPENDIX A:

HVB INTERVAL SUMMARIES

A1. APPENDIX A1: INTERVAL HVB/25.6D

This interval was tested using a double straddle packer assembly with a length of 5.1 m. The upper and lower packer seats were at 23.0 m and 28.1 m, respectively. Testing details are included in NIB 88-02, Section I.

A1.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey marlstone. Fractures were generally filled or partly filled with apertures from less than 2 mm to 14 mm. RQD varied from 5 to 100 percent.

This interval was the first detailed test conducted within the 28.6D screening interval. It was the second to last test done in HVB. Packer seats were selected to cover half the borehole enlargement between 26 and 32 m.

A1.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 28.6D, 48.6D, 69.6D, and 78.9D,
5. Changing of straddle, Casing Test 1, run-in of the testing equipment, and,
6. Detailed tests 42.5D, 47.6D, 52.7D, and 74.5D.

Potential inflow conditions lasted for about 376 hours.

A1.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A1.1, included:

1.	Inflation	INF
2	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
5.	Pulse injection 2	Pi2
6.	Pressure recovery 1	Pr1
7.	Injection test	Qcp
8.	Pressure recovery 2	Pr2
9.	Deflation	DEF

A1.3.1 Interval Response

Testing began with a 2 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 3 hours and the pressure decreased slowly by about 16 kPa indicating the zone was likely tight. Pi1 was done using the FAV and recovered about 90 percent in 76 minutes. The reason the pressure flattened at Point A is not known.

Pi2 was done using the HVT and recovered by about 50 percent in 419 minutes. The response of both pulse tests indicated a low permeability. The FAV was closed for Pr1 to observe the recovery rate with the smaller shut-in volume. This event lasted 622 minutes during which time the pressure decreased to 366 kPa.

The injection pumping equipment was connected and a test run to determine how low a flow rate could be measured with a constant pressure maintained in this tight an interval. An injection pressure of about 720 kPa was applied over the 180 minute event during which time the flow rates decreased from 14.3 to 0.5 ml/min.

The final recovery, Pr2, was monitored for 208 minutes. The pressure fell from 720 to 531 kPa and was still decreasing at the end of testing in the interval.

A1.3.2 Annulus Response

The pressure remained stable at about 312 kPa during the testing period.

A1.3.3 Bottomhole Response

The P1-line surface valve remained closed during the entire testing period.

The initial P1 pressure increase was in response to packer squeeze during inflation. The pressure decayed and stabilized mid-way through the testing period at Point B at a pressure of 158 kPa.

Section A6.3.3 provides more detail on the P1 response.

A1.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It increased by about 5 kPa over the testing period.

A1.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 15.8°C and 16.7°C. The surface probe temperature varied from 19.8°C to 20.1°C.

A1.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

A1.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Despite some irregularities in both the pulse tests, the response characteristics of them both, and the following events, indicated that the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A1.2. The response of the HVT injection test (Pi2) was assigned several decreasing pressures to simulate the tank hydraulic configuration.

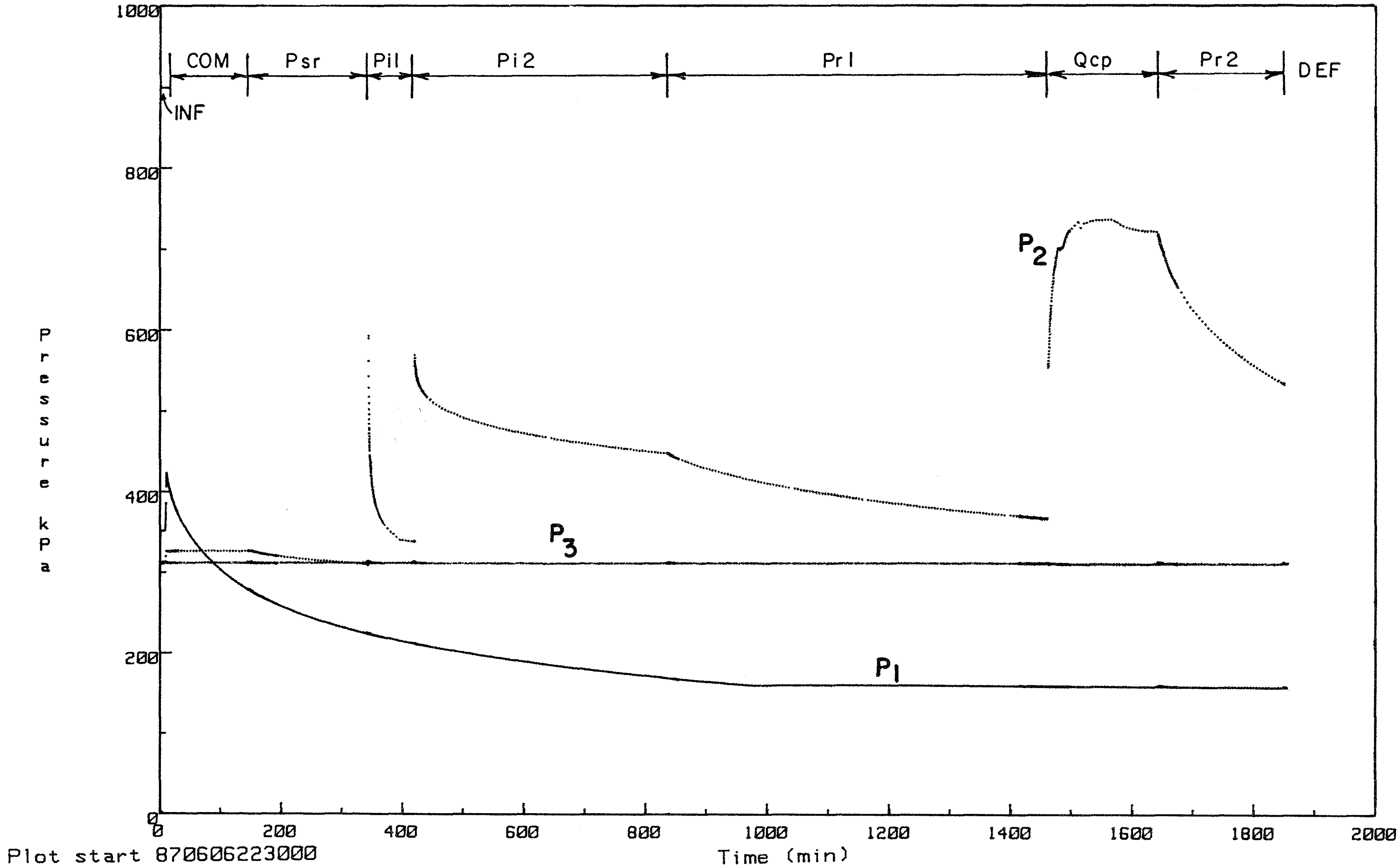
No value of static pressure could be determined from the testing since the zone was too tight. A value of 150 kPa was selected based on the assumed trend of pressures in the borehole. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

A1.4.2 Results

The drilling and prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined. The value at the end of the Psr event was 310 kPA. A value of between 100 and 200 kPa is more reasonable.

The data were able to be bounded, except for the Pi1 event, with hydraulic conductivity between 1e-13 m/s and 4e-13 m/s at a storativity of 5e-4. Assigning a conductivity value of less than 1e-12 m/s was reasonable for the interval response over the wider range of possible storativity values from 5e-7 m/s to 5e-4 m/s and the uncertainty in the Ps value.

The anomalous Pi1 response may have been the result of a gas in the closed chamber, a longer open period of constant pressure than actually occurred or packer compliance.



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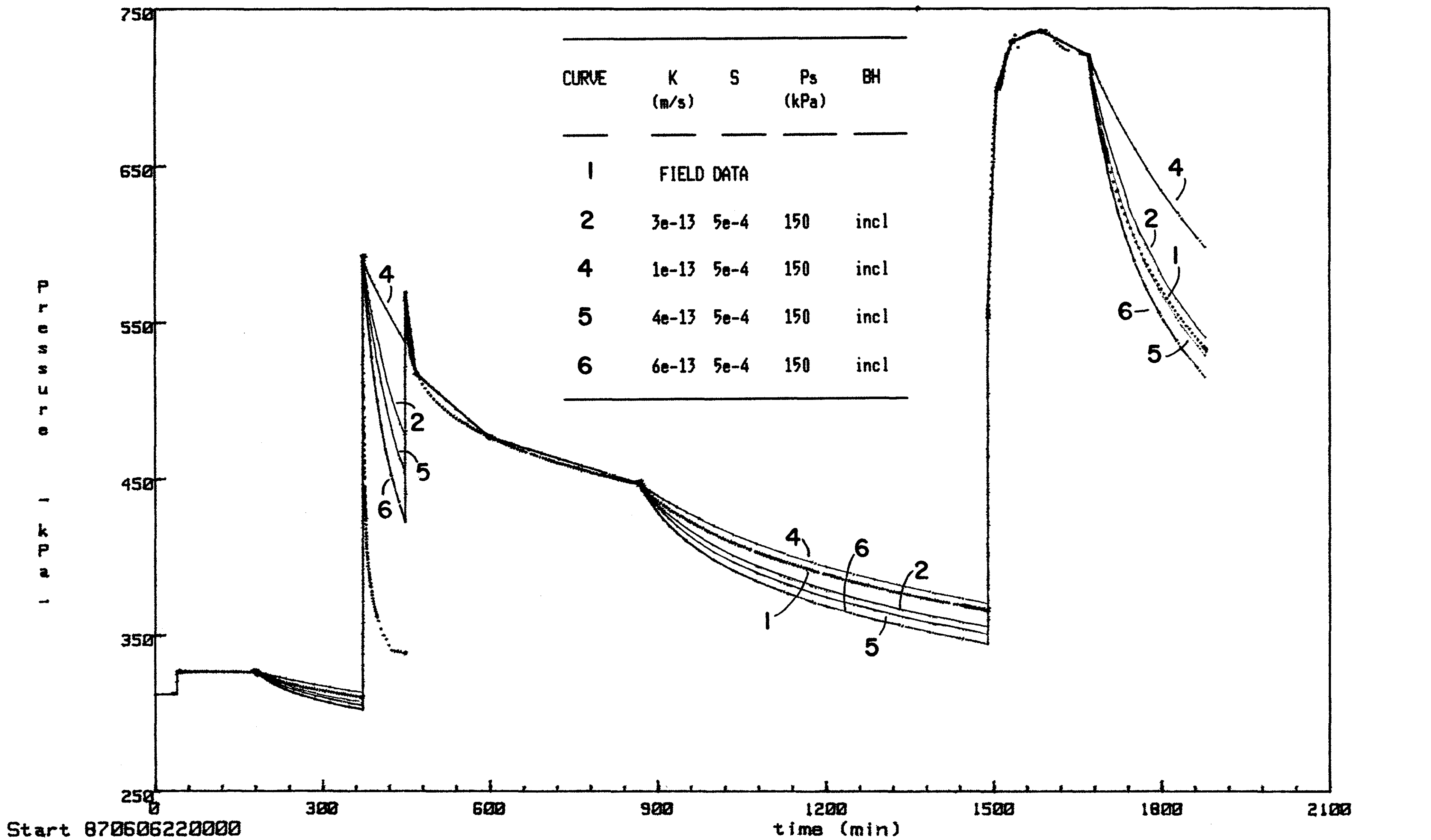
PRESSURE SEQUENCE PLOT - HVB/25.6D



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EXAMPLE SIMULATION - - HVB/25.6D

A2. APPENDIX A2: INTERVAL HVB/28.6D

This interval was tested using a double straddle packer assembly with a length of 20.0 m. The upper and lower packer seats were at 18.5 m and 38.5 m, respectively. Testing details are included in NIB 88-02, Section A.

This interval testing is described in detail in Section 6.1 of this NTB.

A2.1 HYDROGEOLOGICAL SETTING

The interval consisted of fractured grey marlstone. Fractures were primarily along planes and generally filled or partly filled. Apertures ranged from less than 1 mm to 10 mm. RQD varied from 10 to 100 percent.

This interval was both the first test and the first screening test conducted in the borehole. Packer seats were selected to cover the 20 m section of the borehole immediately beneath the casing where there were several caliper anomalies between 96 and 126 mm.

A2.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment.

Potential inflow conditions lasted for about 152 hours.

A2.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A2.1, included:

1.	Inflation	INF
2	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
5.	Slug injection 1	Si1

6. Pressure recovery 1	Pr1
7. Slug withdrawal 1	Sw1
8. Pressure recovery 2	Pr2
9. Blowout Preventer Test	BOP
10. Deflation	DEF

A2.3.1 Interval Response

Testing began with a 3 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 11 hours and the pressure decreased slowly by about 76 kPa indicating the zone was likely tight. The Psr event was longer than expected because the trend in the bottomhole pressure was being closely monitored. Pi1 was done using the FAV and recovered about 83 percent in 100 minutes.

Si1 was done to see if the zone would take any water. The fluid level in the tubing had been observed to fall a few cm when the FAV was opened at the beginning of Pi1. However, the Si1 response was similar to the compliance period with virtually no change in the pressure over a period of 31 minutes. The response of both Pi1 and Si1 indicated a low permeability.

The FAV to closed for Pr1 to observe the recovery back towards a static pressure value. In this instance, the event lasted 117 minutes during which time the pressure decreased from 282 to 220 kPa. Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 160 kPa at the start of Sw1. An under-pressure was used to see if fluid would flow up into the tubing. A small change of 0.2 kPa was recorded during 60 minutes at which time the FAV was closed and the final pressure buildup was monitored.

The final recovery, Pr2, was monitored for 162 minutes. The pressure increased 160 to 171 kPa and was increasing slowly at the end of testing in the interval.

The BOP was tested at the top of the casing. These data are not relevant to the interval response.

The packer inflation line pressure was increased by 11 bars to determine the influence on the interval pressure (Point A). There was a small 2 kPa jump at that time followed by a step decrease. The interval response trend was maintained demonstrating there was no effective influence on the interval pressure from the packer pressure.

A2.3.2 Annulus Response

The pressure remained stable at about 267 kPa during the testing period.

A2.3.3 Bottomhole Response

The P1-to-surface line was reported to have been closed during inflation. It was opened about 6 hours into the testing during the Psr event (Fig A2.1, Point B). The valve was closed at Point C when the pressure was still dropping. Even with the valve closed, the pressure drop continued. The pressure stabilized at Point D and thereafter fluctuated between about 80 and 85 kPa.

Section A6.3.3 provides more detail on the P1 response.

A2.3.4 Packer Pressure Response

The packer pressure was shut-in after inflation. It decreased about 4000 kPa during the first 13 hours of testing. The packer pressure was increased by about 11 bars at Point A on Fig A2.1 After re-pressurization, the packer pressure decreased by about 900 kPa over the testing period to the end of Pr2.

A2.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.4°C and 17.1°C. The surface probe temperature varied from 19.6°C to 20.4°C.

A2.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures during drilling opposite the interval likely influenced the formation response during testing.

A2.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Transient static and non-ideal initial conditions influenced the pulse test analysis. Flow rates for the three flow events were virtually zero. Horner-type analyses of the following recovery periods is not accurate since radial flow conditions were not reached during the flow periods. However, all transient responses indicated that the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A2.2.

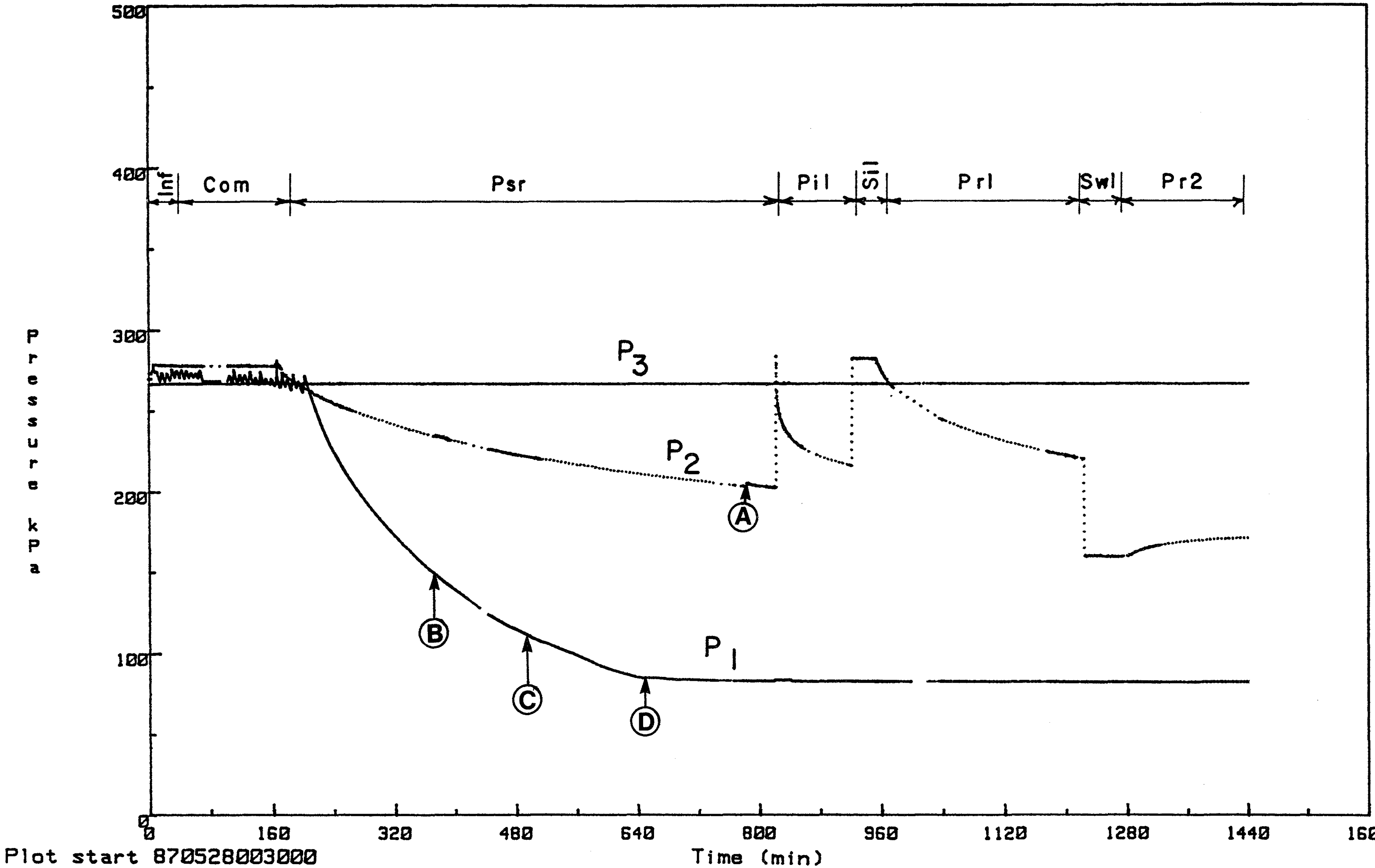
No value of static pressure could be determined from the testing since the zone was too tight. A value of 100 kPa was selected initially based on a knowledge of the borehole history pressures and the decreasing trend of the interval response at the end of the Psr event when it had reached 202 kPa and was still decreasing. At the same time, it was recognized that with this low a conductivity, the sensitivity to changes on the order of 50 to 100 kPa in the static pressure would be low.

A2.4.2 Results

The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

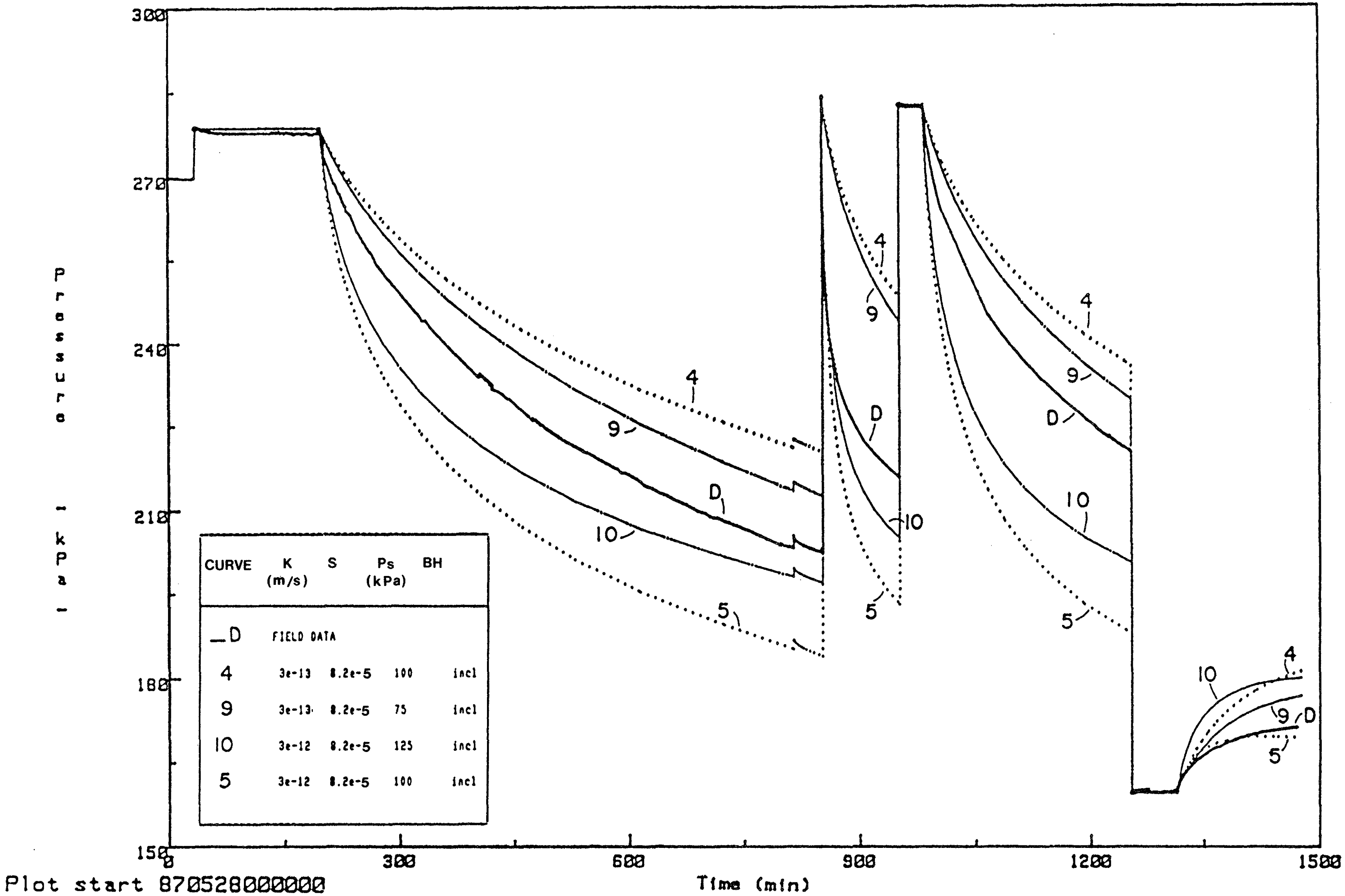
The value at the end of the Psr event was 202 kPA. The value at the end of the Pr2 event was 171 kPa and still increasing. However, this increase, based on the conductivity of the zone was likely still being influenced by the over 6 days time that the fluid level in the borehole was at the level of the drilling gallery floor. A value of 125 kPa or lower is possible for the static pressure in this zone given the potential borehole history influence.

The data was able to be bounded with hydraulic conductivity between 1e-13 m/s and 1e-11 m/s at storativities ranging from 1e-6 to 1e-3. Assigning a conductivity value of less than 1e-11 m/s is reasonable for the interval response over the range of possible storativity values and the uncertainty in the Ps value.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A2.1

PRESSURE SEQUENCE PLOT - HVB/28.6D



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A2.2

EXAMPLE SIMULATION - - HVB/28.6D

A3. APPENDIX A3: INTERVAL HVB/32.0D

This interval was tested using a double straddle packer assembly with a length of 6.1 m. The upper and lower packer seats were at 28.9 m and 35.0 m, respectively. Testing details are included in NIB 88-02, Section J.

A3.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey, fine-grained marlstone with soft clay layers, fractures, small scale folds and layering offsets. Fractures were generally filled or partly filled. RQD varied from 30 to 50 percent.

This interval was the second detailed test conducted within the 28.6D screening interval. It was the last test done in HVB. Packer seats were selected to cover the lower half the borehole enlargement between 29 and 34 m.

A3.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 28.6D, 48.6D, 69.6D, and 78.9D,
5. Changing of straddle, OBS1/Casing Test, run-in of the testing equipment,
6. Detailed tests 42.5D, 47.6D, 52.7D, 74.5D, and 25.6D, and,
7. Run-out, repair equipment and change straddle and run-in.

Potential inflow conditions lasted for about 420 hours.

A3.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A3.1, included:

1.	Inflation	INF
2	Compliance	COM

3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Deflation	DEF

A3.3.1 Interval Response

Testing began with a 2 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 11 hours and the pressure decreased slowly by about 70 kPa indicating the zone was likely tight. The end pressure was 301 kPa. The extended time for the Psr was provided in the hope that a better static could be obtained during this test than had been obtained during the HVB/28.6 and HVB/25.6D tests completed previously.

Pi1 was done using the FAV and recovered about 85 percent in 239 minutes. Testing was terminated after this single test due to the apparent low permeability of the interval. The available additional time would not be adequate to document the zone static pressure.

A3.3.2 Annulus Response

The pressure remained stable at about 360 kPa during the testing period.

A3.3.3 Bottomhole Response

The P1-line surface valve remained closed during the entire testing period.

The initial P1 pressure increase was in response to packer squeeze during inflation. The pressure continued to decay over the duration of testing. The decrease between Points A and B (Figure A3.1) is unexplained.

A3.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by 36 kPa over the testing period.

A3.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.2°C and 16.7°C. The surface probe temperature varied from 19.5°C to 20.0°C.

A3.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

A3.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The normalized pressure plot of the Pi1 event did not match well with the type curves. Despite this, the response indicated a relatively low conductivity.

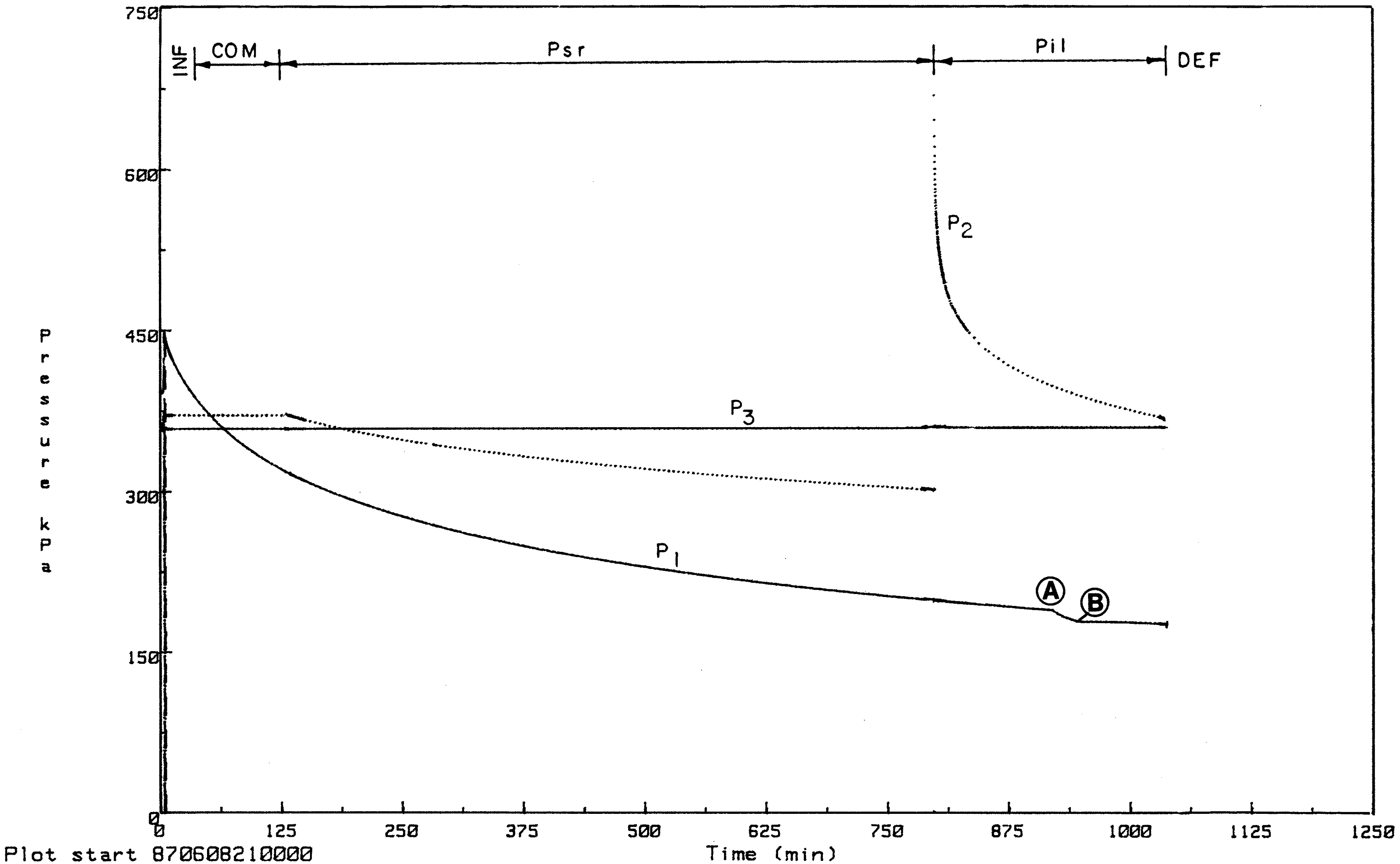
The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A3.2.

No value of static pressure could be determined from the testing since the zone was too tight. A value of 200 kPa was initially selected based on the assumed trend of pressures in the borehole. At the same time, it was recognized that with this low a conductivity, the sensitivity to changes in the static pressure would be low.

A3.4.2 Results

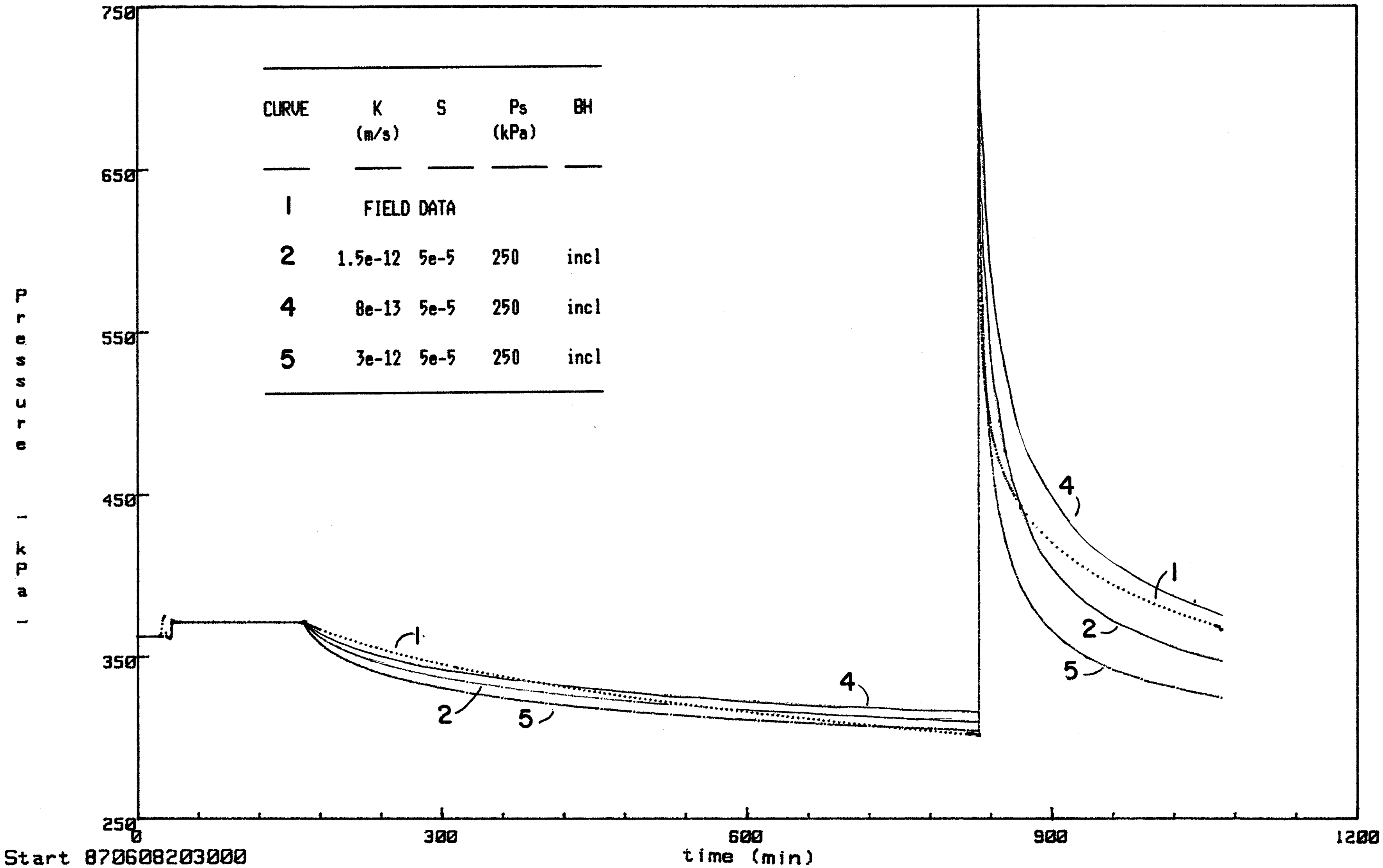
The drilling and prior testing affected the pressures in the vicinity of the borehole prior to and during the testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined. The value at the end of the Psr event was 301 kPA and still decreasing. A value of between 150 and 250 kPa is more reasonable.

The data were able to be bounded with hydraulic conductivity between 8e-13 m/s and 3e-12 m/s at a storativity of from 5e-7 to 5e-4. Assigning a conductivity value of less than 2e-12 m/s is reasonable for the interval response over the wider range of possible storativity values and the uncertainty in the Ps value.



NAGRA / GLAG | NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | A3.1

PRESSURE SEQUENCE PLOT - HVB/32.0D



NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | A3.2

EXAMPLE SIMULATION - - HVB/32.0D

A4. APPENDIX A4: INTERVAL HVB/42.5D

This interval was tested using a double straddle packer assembly with a length of 5.1 m. The upper and lower packer seats were at 40.0 m and 45.1 m, respectively. Testing details are included in NIB 88-02, Section E.

A4.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey marlstone. Fractures were generally filled or partly filled with apertures from 2 mm to 4 mm. RQD varied from 75 to 100 percent.

This interval was the first of three detailed tests conducted within the 48.6D screening interval. Packer seats were selected to assess the hydraulic conductivity of the rock matrix. No caliper anomalies were in the section.

A4.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 28.6D, 48.6D, 69.6D, and 78.9D, and,
5. Changing of the straddle and Casing Test 1.

Potential inflow conditions lasted for about 290 hours.

A4.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A4.1, included:

1.	Inflation	INF
2	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
5.	Deflation	DEF

A4.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted 113 minutes and the pressure increased slowly by 12 kPa indicating the zone was likely tight. The increase in pressure was unusual and probably was caused by continuing packer expansion.

Pi1 was done using the FAV and recovered a total of about 25 percent in 295 minutes. The reason for the initial rapid pressure decrease during Pi1 to Point A (Figure A4.1) is not known.

The testing was terminated at the end of the Pi1 event since the low hydraulic conductivity of the matrix rock had been documented.

A4.3.2 Annulus Response

The pressure remained stable at about 480 kPa during the testing period.

A4.3.3 Bottomhole Response

The P1-line surface valve remained closed during the entire testing period.

The P1 pressure increases (Points B and C, Figure A4.1) were in response to packer squeeze during inflation. The pressure decayed after the second peak and continued to decrease over the duration of testing.

A4.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 10 kPa over the testing period.

A4.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.3°C and 16.8°C. The surface probe temperature varied from 19.3°C to 19.8°C.

A4.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

A4.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The relatively small recovery percentage made a unique match with the type curves difficult for the Pi1 event. Despite this, it was evident that the zone had relatively low conductivity.

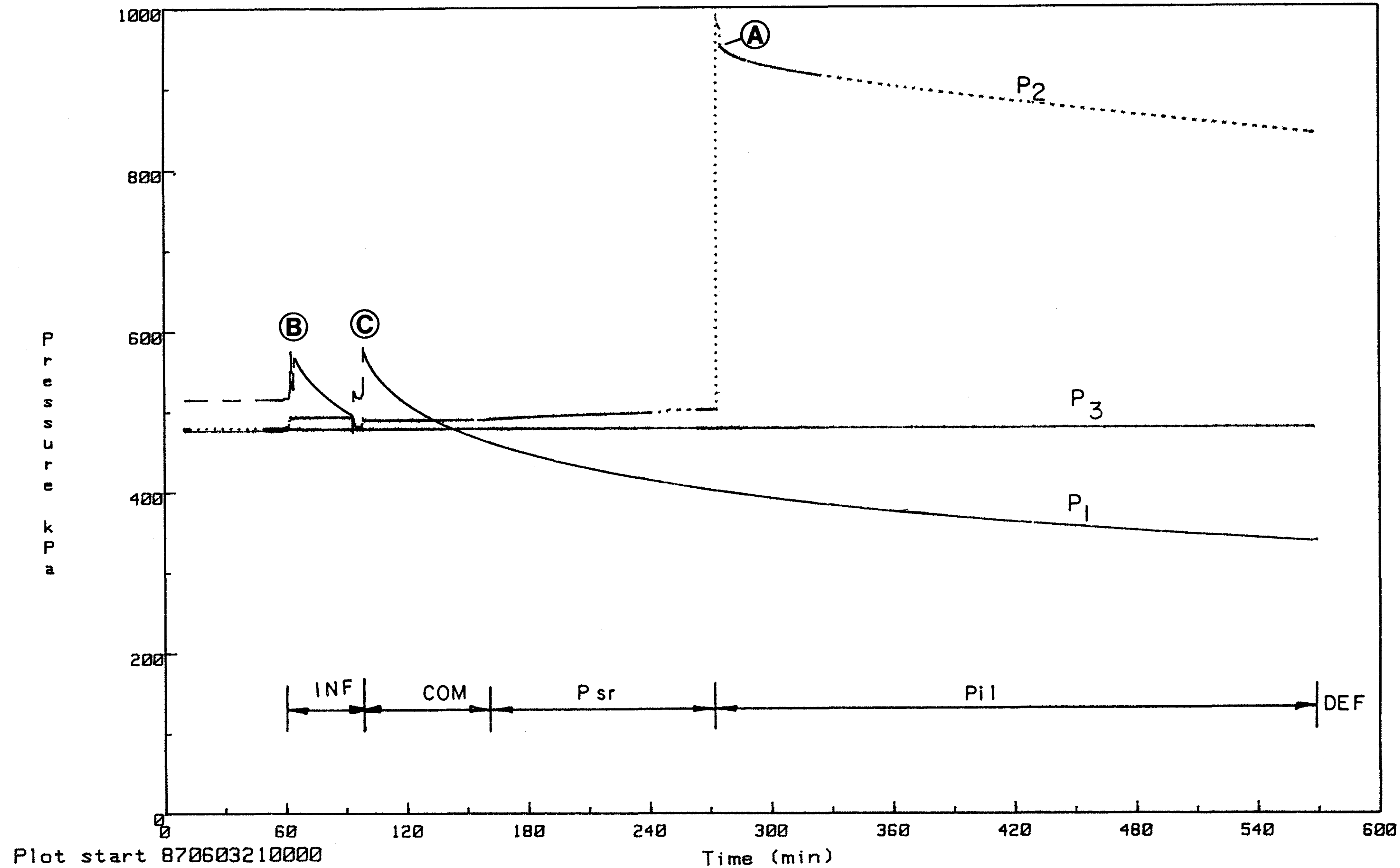
The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A4.2. The increase during the Psr event was assigned a linearly increasing pressure. The initial pressure drop in Pi1 was simulated as a matched condition. Therefore, the only data that were bounded were those in the latter part of the Pi1 event.

No value of static pressure could be determined from the testing since the zone was too tight. A value of 150 kPa was selected initially, but analyses were done over a range from 150 to 400 kPa. With this low a conductivity, the sensitivity to changes in the static pressure were low.

A4.4.2 Results

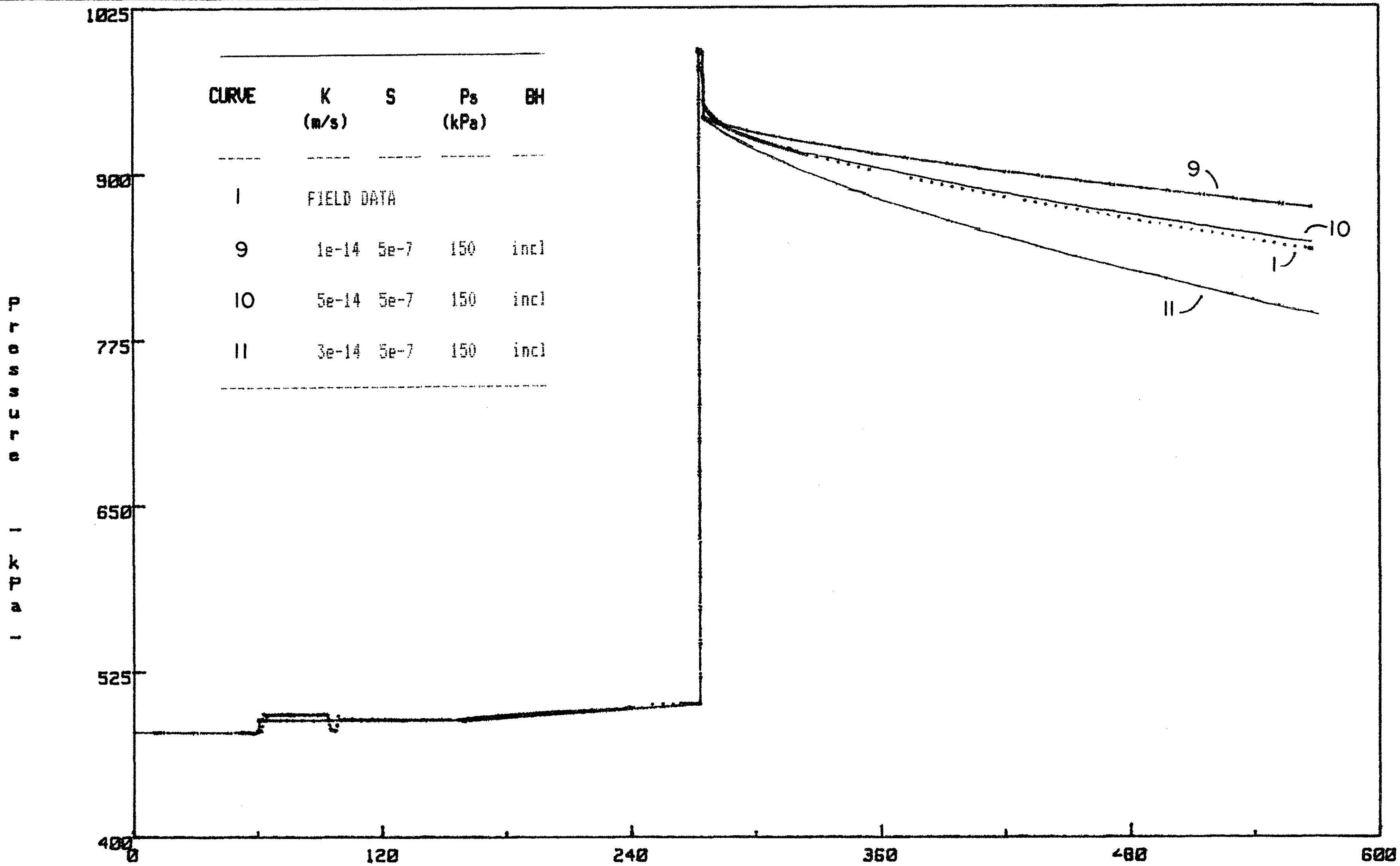
The drilling and prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined. The pressure increased during Psr in response to non-formation conditions. No more accuracy than between 150 and 400 kPa is considered reasonable.

The data were able to be bounded with hydraulic conductivity between 1e-14 m/s and 2e-13 m/s at a storativity between 5e-7 and 5e-4. Assigning a conductivity value of less than 1e-13 m/s was reasonable for the interval response over the wider range of possible storativity values and the uncertainty in the static pressure value.



NAGRA / GLAG **NTB: 88-03** **OBERBAUENSTOCK** DAT.: APR. 88 A4.1

PRESSURE SEQUENCE PLOT - HVB/42.5D



Start 870603210000

NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A4.2

EXAMPLE SIMULATION - - HVB/42.5D

A5. APPENDIX A5: INTERVAL HVB/47.6D

This interval was tested using a double straddle packer assembly with a length of 5.1 m. The upper and lower packer seats were at 45.0 m and 50.1 m, respectively. Testing details are included in NIB 88-02, Section F.

A5.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey marlstone. Fractures were generally filled or partly filled with apertures from less than 2 mm to 15 mm. RQD varied from 65 to 90 percent.

This interval was the second of three detailed test conducted within the 48.6D screening interval. Packer seats were selected to cover the borehole enlargement at about 47 m.

A5.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 28.6D, 48.6D, 69.6D, and 78.9D,
5. Changing of straddle, Casing Test 1, run-in of the testing equipment, and,
6. Detailed tests 42.5D.

Potential inflow conditions lasted for about 300 hours.

A5.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A5.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Pressure recovery 1	Pr1
7. Injection test 1	QI-1
8. Injection test 2	QI-2
9. Pressure recovery 2	Pr2
10.Deflation	DEF

A5.3.1 Interval Response

Testing began with a 30 minute compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 4 hours and the pressure decreased by about 108 kPa indicating the zone was likely tight. Pi1 was done using the FAV and recovered about 90 percent in 47 minutes.

Pi2 was done using the HVT and recovered by about 38 percent to 554 kPa in 573 minutes. The response of both pulse tests indicated a low permeability. The FAV was closed for Pr1 to observe the recovery rate with the smaller shut-in volume. This event lasted 290 minutes during which time the pressure decreased to 457 kPa.

The injection pumping equipment was connected and a test run to determine how constant a flow rate could be maintained and what type of pressure increase would occur with two different flow rates. An injection rate of between 0.5 and 1 ml/min carried out over a period of 148 minutes resulted in a pressure increase of 114 kPa. Difficulties were encountered maintaining this low flow rate and it was increased to 2 ml/min for the second injection phase. Pressures increased much more rapidly rising to 933 kPa in about 127 mnutes.

The final recovery, Pr2, was monitored for 289 minutes. The pressure fell to 535 kPa and was still decreasing at the end of testing in the interval.

A5.3.2 Annulus Response

The pressure remained stable at about 525 kPa during the testing period.

A5.3.3 Bottomhole Response

The P1-line surface valve remained closed during the entire testing period.

The initial P1 pressure increase was in response to packer squeeze during inflation. The pressure decayed at a consistently decreasing rate during the testing and was at a value of 269 kPa at the end of testing.

A5.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 40 kPa over the testing period.

A5.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.5°C and 16.9°C. The surface probe temperature varied from 19.8°C to 19.9°C.

A5.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval influenced the formation response during testing.

A5.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The final recovery period field analysis indicated a hydraulic conductivity about two orders of magnitude greater than that obtained from the type-curve matching of the two pulse tests. Despite this analysis difference, the response characteristics of all tests indicated that the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A5.2. The response of the HVT injection test (Pi2) was assigned several decreasing pressures to simulate the tank hydraulic configuration.

No value of static pressure could be determined from the testing since the zone was too tight. A value of 150 kPa was initially selected, but sensitivity analysis was done over a range as high as 400 kPa. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

A5.4.2 Results

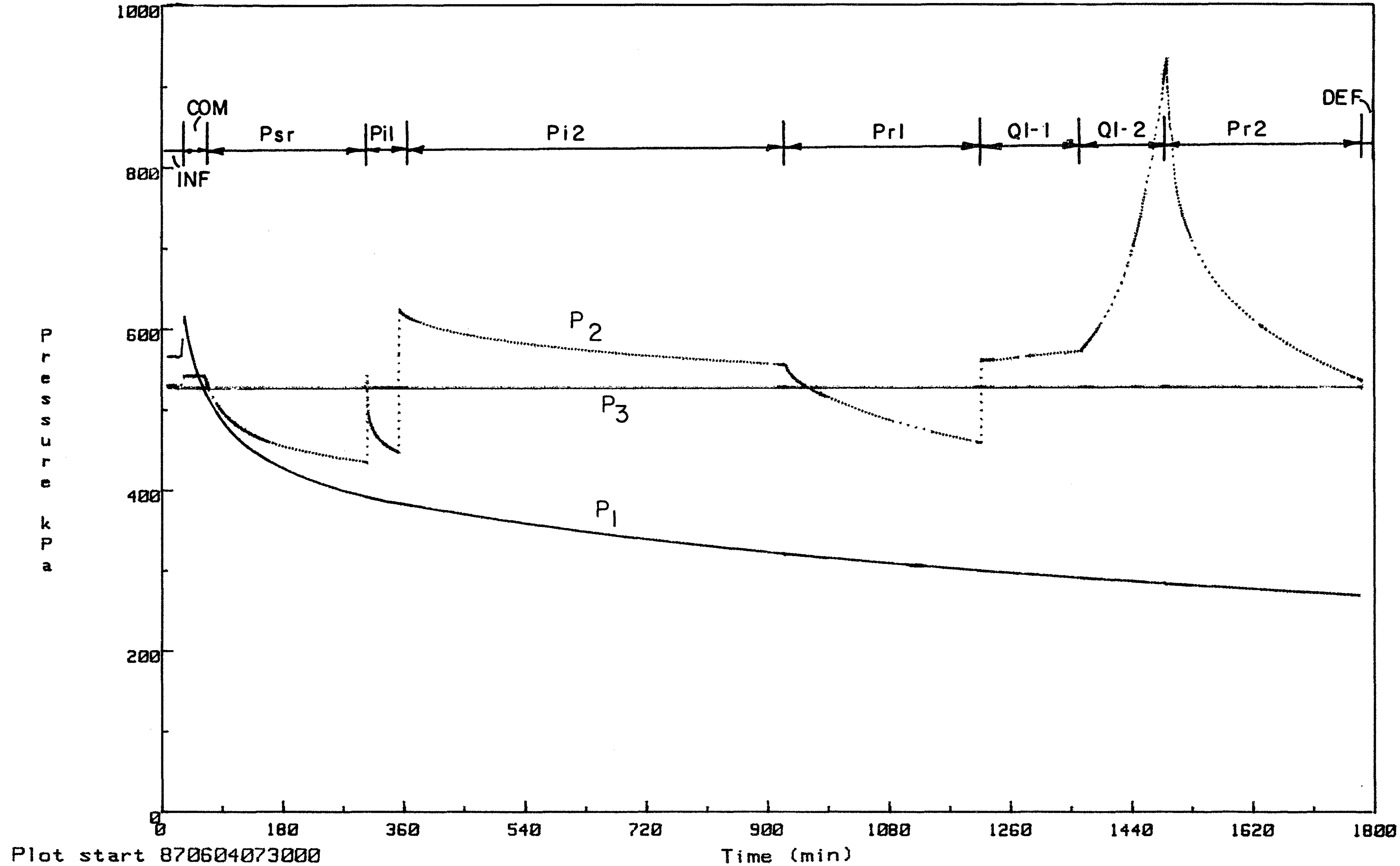
The drilling and prior testing affected the pressures in the vicinity of the borehole prior to and during testing. Borehole history pressures were generally in the range of 500 to 600 kPa. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined. The value at the end of the Psr event was 434 kPA and still decreasing. No more accuracy than a value of between 150 and 400 kPa is considered reasonable.

The data were able to be bounded, but a relatively wide range of hydraulic conductivity between 3e-12 m/s and 1e-10 m/s resulted when the storativity was varied between 5e-7 and 5e-4. Use of a higher pressure than 150 kPa would in general increase the hydraulic conductivity required to achieve the same bounding, if other conditions remained the same.

The pressure response during the events was not consistent throughout testing. The injection and final recovery events indicated faster responses than the initial pulses and recovery event. All simulations attempts indicated the same relative change in response pattern. The conductivity upper bounding limit of 1e-10 m/s for a low storativity of 5e-7 was correct for the final injection and recovery rates. However, the value needed to bound the earlier events was at least one order of magnitude less.

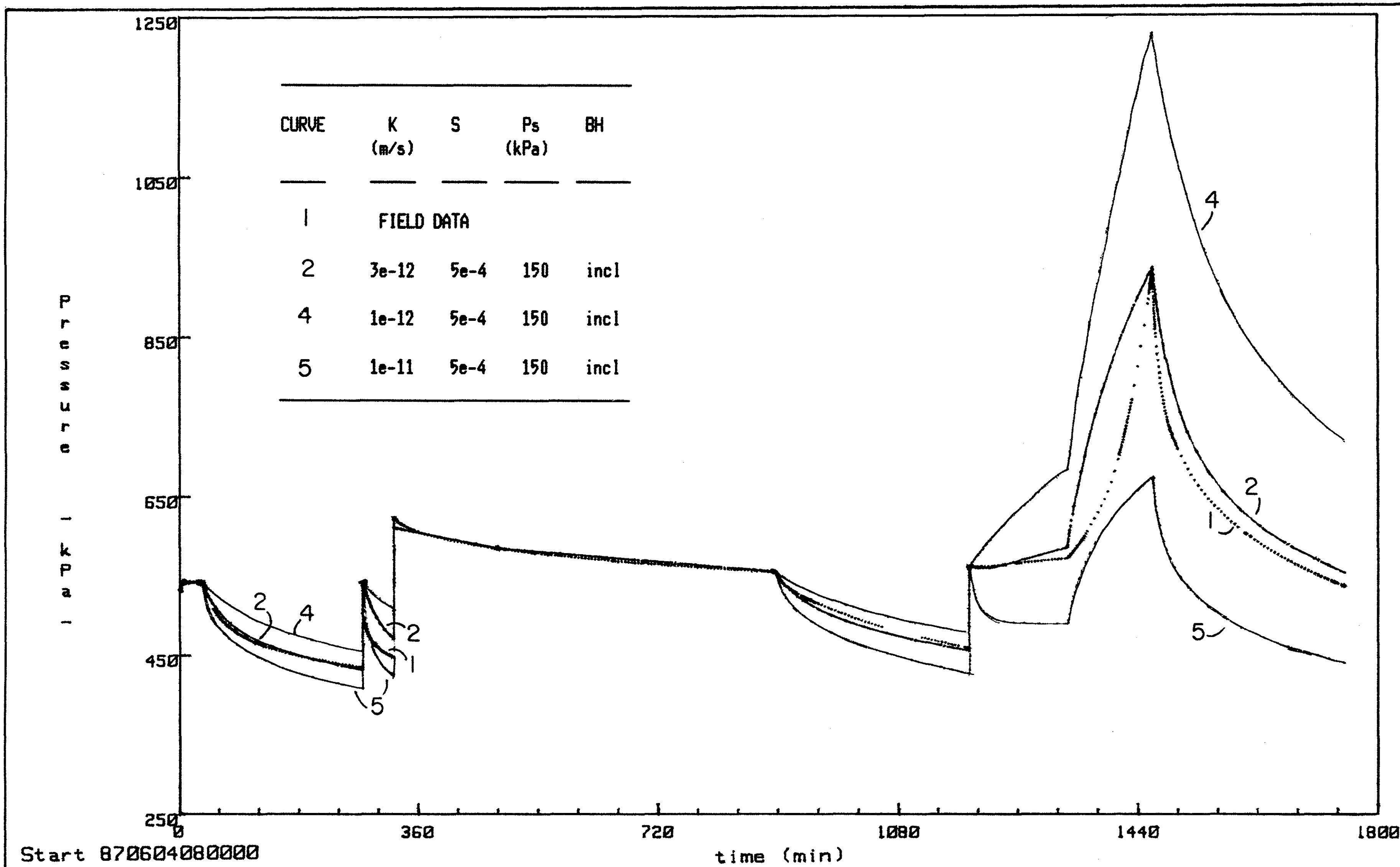
In addition, none of the simulations attempted were able to duplicate the concave upwards shape of the QI-2 event. The apparent change in conductivity and the pressure response shape difference between all the simulations and the data may be related to a fracture rather than porous medium environment for this interval.

The bounding approach resulted in a relatively wide range of parameter values for this interval reflecting their uncertainty.



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A5.1

PRESSURE SEQUENCE PLOT - HVB/47.6D



CURVE	K (m/s)	S	Ps (kPa)	BH
1	FIELD DATA			
2	3e-12	5e-4	150	incl
4	1e-12	5e-4	150	incl
5	1e-11	5e-4	150	incl

NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A5.2

EXAMPLE SIMULATION - - HVB/47.6D

A6. APPENDIX A6: INTERVAL HVB/48.6D

This interval was tested using a double straddle packer assembly with a length of 20.0 m. The upper and lower packer seats were at 38.5 m and 58.5 m, respectively. Testing details are included in NIB 88-02, Section B.

A6.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey marlstone. Fractures were primarily along planes and generally filled or partly filled. Apertures ranged from 1 mm to 10 mm. RQD varied from 25 to 100 percent.

This interval was the second test and the second of four screening test conducted in the borehole. Packer seats were selected to cover the 20 m section of the borehole immediately beneath the HVB/28.6D interval. Two caliper anomalies showed deviation to about 106 mm.

A6.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment, and,
4. Testing of the HVB/28.6D screening interval.

Potential inflow conditions lasted for about 156 hours.

A6.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A6.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Slug injection 1	Si1
6. Pressure recovery 1	Pr1
7. Slug withdrawal 1	Sw1
8. Pressure recovery 2	Pr2
9. Deflation	DEF

A6.3.1 Interval Response

Testing began with a 3 hour compliance period during which time the interval pressure declined by 1.3 kpa. The Psr lasted 67 minutes and was terminated too early. The pressure had decreased by 95 kpa and was still decreasing relatively rapidly. Pi1 was done using the FAV and recovered to within 3 kpa of the value at the end of Psr within 25 minutes. The trend at the end of Pi1 was similar in shape and response characteristics to the point at which the Psr had ended.

Si1 was done to see if the zone would take any water. The fluid level in the tubing had dropped during compliance and the Pi1 response was complete recovery in less than 30 minutes. The Si1 response was similar to the compliance period with a small 0.4 kpa change in 13 minutes. The response of both Pi1 and Si1 indicated a higher permeability than in the HVB/28.6D screening interval, but still not adequate to conduct any prolonged slug-type testing.

The FAV to closed for Pr1 to observe the recovery back towards a static pressure value. In this instance, the event lasted was prolonged in the hope of determining a representative static pressure. Pr1 lasted about 27 hours during which time the pressure decreased from 470 to 251 kpa. The pressure was still decreasing at the end of Pr1. Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 166 kpa at the start of Sw1. An underpressure was used to see if fluid would flow up into the tubing. Flow did occur and the interval pressure increased by 2.1 kpa during 72 minutes. At this time, the FAV was closed and the final pressure buildup was monitored.

The final recovery, Pr2, was monitored for 219 minutes. The pressure increased 168 to 213 kpa and was increasing slowly at the end of testing in the interval.

The P1 bottomhole pressure was increased twice during the Pr1 event to determine the influence on the interval pressure as shown on Figure A6.1. This is described in more detail in Section A6.3.3 below. As seen on Figure A6.1, the interval response trend was maintained demonstrating there was no effective influence on the interval pressure from the bottomhole pressure changes.

A6.3.2 Annulus Response

The pressure remained stable at about 460 kpa during the testing period.

A6.3.3 Bottomhole Response

The P1 surface valve was opened about 6 hours into testing during the Pr1 event (Figure A6.1, Point A). The P1 pressure at that point was about 110 kpa, only about 15 kpa greater than atmospheric pressure of about 95 kpa. The pressure immediately increased by about 130 kpa (Point B) when the surface valve was opened and then began to decrease. This is the expected response given that by opening the valve, atmospheric pressure is suddenly applied and responded to in the formerly closed system. The following decay is a reflection of the falling water level under open conditions. The decay was observed for about 2 hours.

At that time, the P1 line-to-surface was subjected to a 300 kpa compressed air source and the pressure increased accordingly (Figure A6.1, Point C to D). This was done to both evaluate the bottomhole pressure response and to observe if there was any affect on the interval pressure. A pressure of about 450 to 460 kpa was maintained for about 4 hours during which time there was no response observed in the interval. The P1 surface valve was then closed (Figure A6.1, Point E) and the bottomhole pressure decayed until the end of testing (Point F). The final bottomhole pressure was 294 kpa.

The pressure fluctuations seen when the compressed air line was initially attached to the P1 line (Figure A6.1, Point D) may have been caused by the movement of water around the cable reel causing small pulses on the P1 transducer.

The following discussion is intended as an explanation of the dynamics of the bottomhole responses seen during the times when the P1 valve at the surface was both closed and open. Figure A6.2 illustrates schematically the surface hydraulics connected to the downhole transducer and the bottomhole zone.

P1 Surface Valve Closed

During the testing of the HVB/48.6D interval, the unusual P1 responses, characteristic of much of the Oberbauenstock testing, are well displayed. As a result, an explanation is included with this interval report and is referenced by other interval reports bearing similar features.

Many of the observed responses stem from the configuration of the equipment and in particular from the following three items:

1) the 1/4 inch stainless steel tube from the surface to the interval
2) the reel at the well head upon which the excess line is stored, and,
3) the P1 shut-in valve at surface.

This location of the P1 valve is important. If this valve had been located at the level of the testing tool (as in the case of the P2 shut-in valve), many of the observed responses would not have occurred.

During the testing of the HVB/48.6D interval, the P1 bottomhole pressure response appears to be influenced by the formation of water vapour in the P1 surface line. This is suggested by two features shown on Figure A6.1.

1) the change in slope of the P1 decay curve mid-way through the Compliance period, and,
2) the large pressure increase that occurred when the P1 surface valve was opened.

The first noteable response is the pressure spike resulting from packer squeeze during inflation. This substantiates the fact that the P1 surface valve was in fact closed.

The pressure spike quickly dissipates as the pressure falls rapidly to a point about 100 kpa less than the initial P1 pressure prior to inflation (Figure A6.1, Point G).

Feature 1, as described above, now occurs. The shape of the decay curve suddenly changes from about 1.8 kpa/min to 0.80 kpa/min. The P1 system is made up of a semi-permeable interval (either above, within or below the water table) and a rigid system of steel tubes connect it to surface. At the beginning of a test, a pressure differential exists between the interval and the adjacent rock. As a result, flow occurs. In most cases, the media pressure is less, as the P1 pressure decreases to an equilibrium. Flow is therefore out of the interval. However, because the system is closed, no air can enter to replace the draining water and the rate of pressure drop is therefore related to the compressibility of water.

If a pressure transducer was located at the top of the system (the surface cable reel), the pressure would initially read about 100 kpa reflecting atmospheric pressure locked in when the P1 surface valve was closed. As the test progresses, water drains from the interval and the pressure decreases. When or if the pressure decreases to 2.5 kpa absolute pressure, the water starts to 'boil' and produces vapour. This is known as the vapour pressure. This will cause a decrease in the slope of the decay curve given that a unit volume of water produces larger volumes as vapour.

Until this point, the water level in the system has remained constant at the surface. The pressure decrease is strictly a result of the expansion of the water. Following the formation of vapour, the liquid water level starts to drop.

Once vapour has formed in the reel, the response may be hindered by unsteady state flow. This is seen as a cyclic P1 response. This can be explained given that the vapour bubble will first appear at the top of the system, likely somewhere in the top of the cable reel. However, as the water level in the system starts to drop, the vapour bubble is not only growing, but must also re-adjust it's position to maintain a pressure equilibrium in the reel. This is achieved by pockets of water travelling from behind the bubble to in front of the bubble. The complexity of this phenomena is further compounded by the probable existence of several bubbles.

The outcome of this scenario is that the pressure fluctuates in a cyclic fashion until the water and vapour in the reel reach some form of pressure equilibrium. Steady state flow is then once again regained as the water level starts to drop down the tube to the tool.

A good example of this sequence of phenomena is seen in Figure A8.1 (HVB/69.6D). Following a 100 kpa pressure drop, a series of pressure cycles occurs followed by a reduced pressure decay slope.

Figure A6.1 is peculiar as no fluctuations are associated with the formation of vapour. This suggests that the water level immediately started to drop down the line to the tool. No equilibrium cycles were necessary.

The second noteable response is that once the pressure drops to the point where water vapour forms, the system is essentially relieved of atmospheric pressure. The P1 transducer is therefore reading only the height of the column of water above it. Readings can theoretically drop to zero.

A good example of this is seen in Figure A6.1. When the surface valve is opened, atmospheric pressure is suddenly added to the P1 pressure. The actual increase is slightly more than 100 kpa. This can be attributed to pockets of water trapped in the surface reel (therefore not affecting the transducer) that are pushed out of the reel and down the line by atmospheric pressure. Once in the line, they are detected by the transducer.

P1 Surface Valve Open

The previous discussion has dealt with situations that arise when the P1 surface valve is closed. However, in a number of tests, the P1 surface valve was open throughout the testing period. A typical response in this situation is seen in Figure A2.1. As the valve is open, there is no pressure response to packer inflation; rather a series of sawtooth cycles occurs as the water is being drawn out of the reel, down the line and out of the interval. The sawtooth appearance results from the water progressing around the reel as the coils are being evacuated. This is often followed by a rapid pressure decline interrupted by steady state conditions. This occurs when the level of the declining water level drops below Point A in Figure A6.2. The transducer is influenced by the negative pressure imposed by the column of water trapped in Tube B. It is also evident that any changes in the fluid level below this point will go undetected by the P1 transducer. This explains why the P1 pressure occasionally levels out at a value less than atmospheric pressure. If air were introduced into this tube, the steady state pressure would be greater.

Until now, it has been assumed that the system is free of all air bubbles. This may be a reasonable assumption for tests performed immediately following the surface maintenance of the tool as all air pockets were evacuated at this time. However, following several interval tests, both air and water vapour may have been introduced in positions within the tool from which they cannot escape. The affect of air bubbles is uncertain but they may cause a dampening effect and unsteady state conditions.

We conclude that the use of the P1 line to surface resulted in explainable conditions in most instances. In future, however, we do not consider it worthwhile to use this feature to attempt to conduct testing in an interval to yield documentable hydraulic parameter values.

A6.3.4 Packer Pressure Response

The packer pressure inflation line valve was shut-in after inflation. The pressure decreased by about 2000 kpa in a consistent manner during testing.

A6.3.5 Temperature Response

Temperatures at sensor depth increased by about 0.8°C during the first 24 hours of testing to about 16.8°C and then decreased to about 16.5°C. The surface probe temperature was stable at about 19.6°C.

A6.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures during drilling opposite the interval likely influenced the formation response during testing.

A6.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Transient static and non-ideal initial conditions would have markedly influenced the Pi1 test analysis using type-curve matching. Instead, field analysis was done with GLIMPSE but without including borehole history.

The results indicated hydraulic conductivity values in the range of 1e-11 m/s to 1e-10 m/s using a static pressure of 370 kpa and a storativity of 1e-5.

The flow rate for the Si1 event was virtually zero. Even the Sw1 event was too low to reach radial flow conditions. Therefore, the Horner-type analyses were not considered accurate. However, all transient responses indicated that the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A6.3.

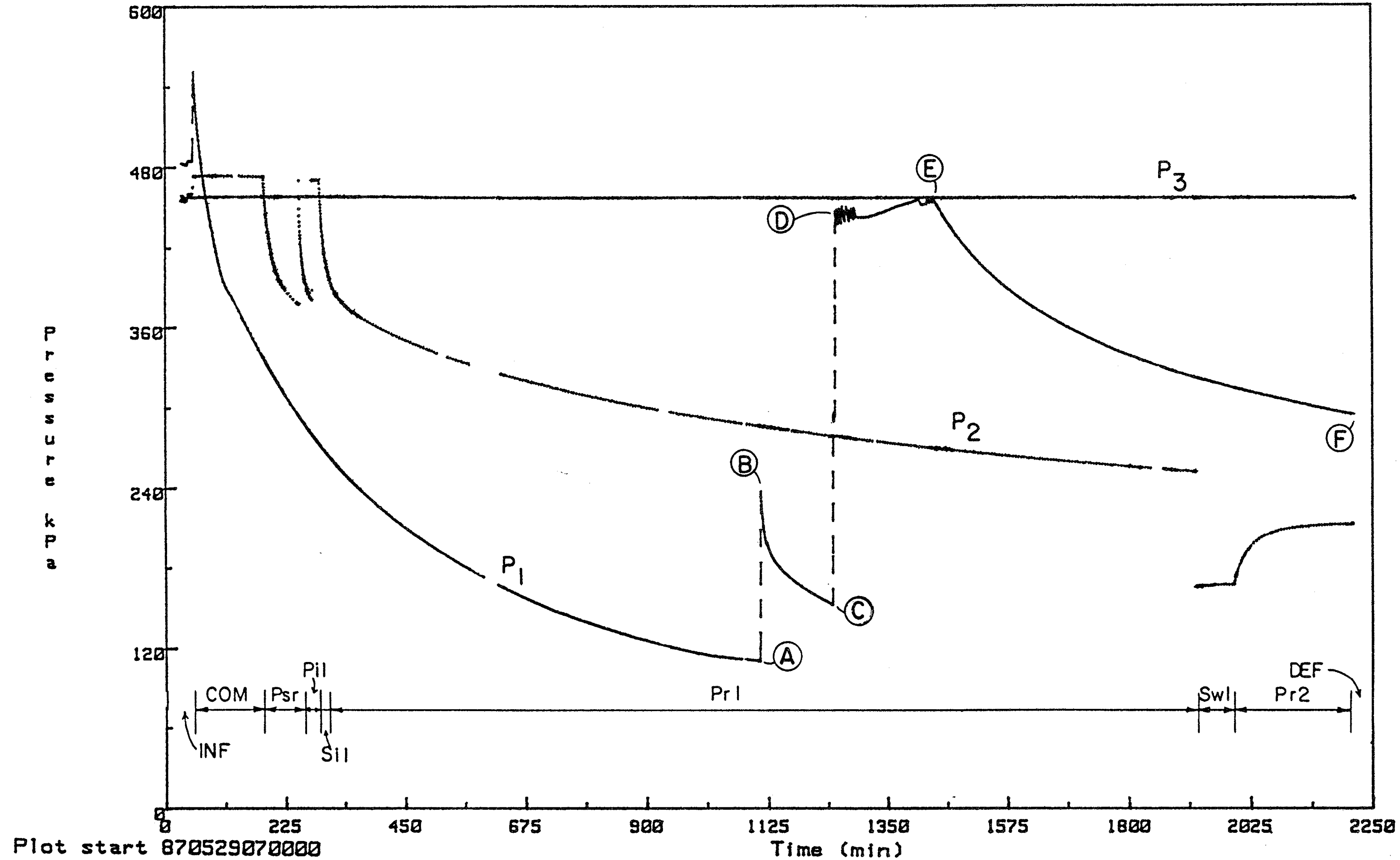
No value of static pressure could be determined from the testing since the zone was too tight. A value of 130 kpa was selected initially based on a knowledge of the borehole history pressures and the decreasing trend of the interval response at the end of the Pr1 event. Sensitivity analyses were done with static pressure values as high as 215 kpa. With this low a conductivity, the sensitivity to changes on the order 100 kpa in the static pressure would be low.

A6.4.2 Results

Borehole history pressures were in the range of 450 to 500 kpa for the 5 days of pretesting activities in the borehole. Pressures opposite the interval decreased and were generally less than about 250 kpa during the previous HVB/28.6D screening test. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

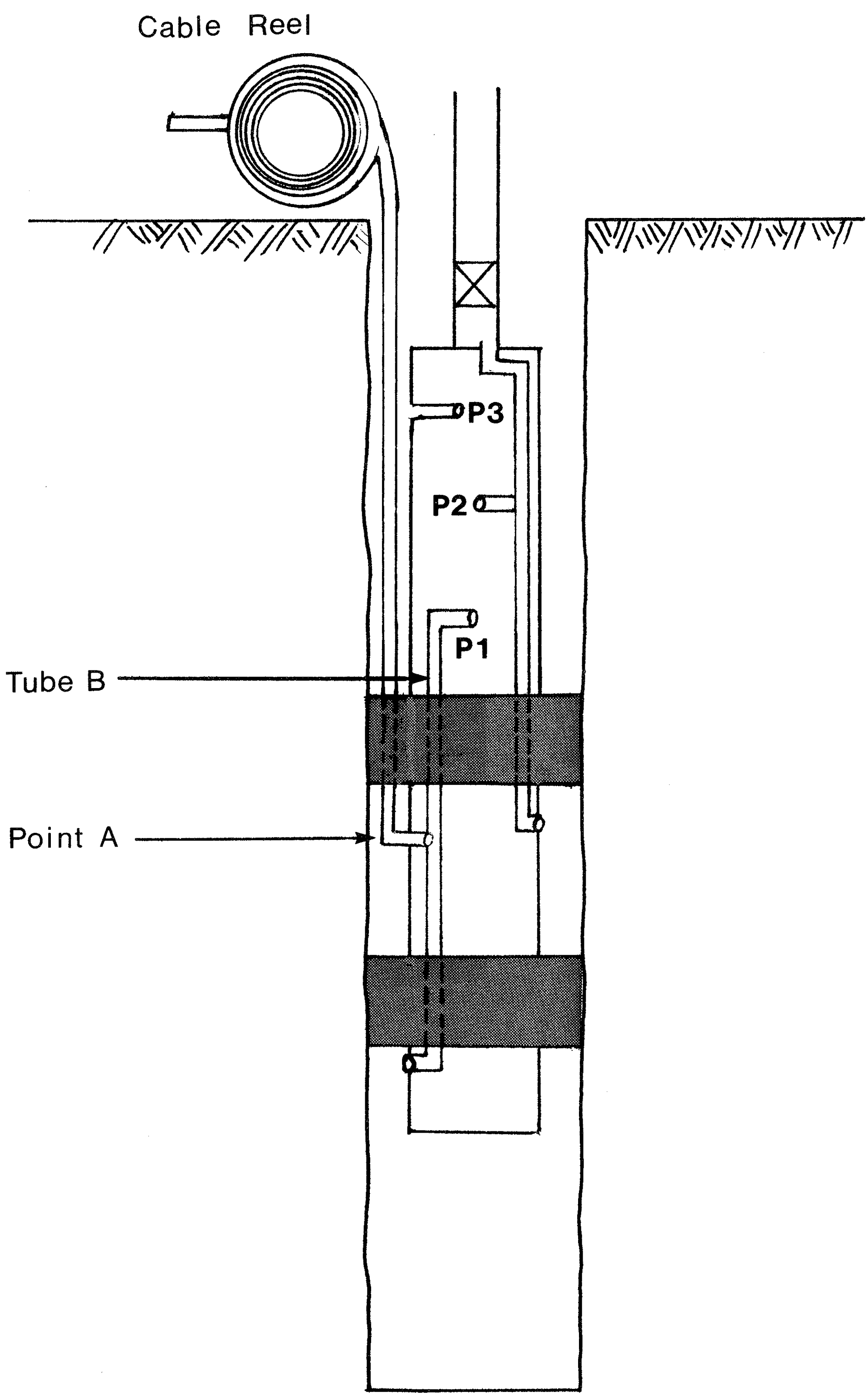
The value at the end of the Psr event was 202 kpa. The value at the end of the Pr2 event was 171 kpa and still increasing. However, this increase, based on the conductivity of the zone was likely still being influenced by the 5 days time that the fluid level in the borehole was at the level of the drilling gallery floor. A value in the range of 130 to 215 kpa is possible for the static pressure in this zone given the potential borehole history influence. However, the model response using the higher static pressure did not have as consistent bounding compared to the results using the lower static pressure value.

The data was able to be bounded with conductivity values on the order of 1e-12 m/s to 2e-11 m/s with storativity ranging from 1e-5 to 1e-3. Assigning conductivity values in this range is reasonable for the interval response over the range of possible storativity values and the uncertainty in the Ps value.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A6.1

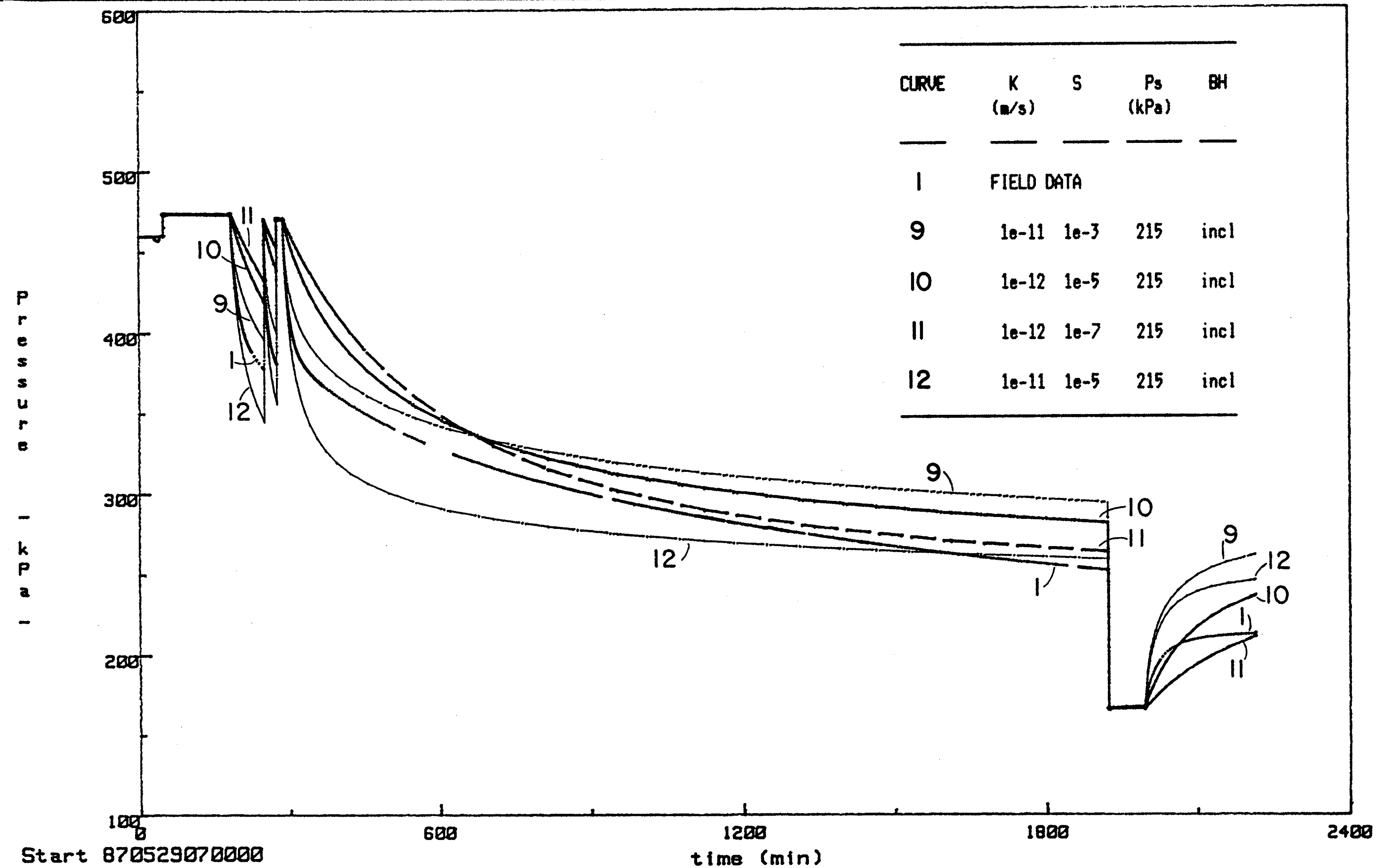
PRESSURE SEQUENCE PLOT - HVB/48.6D



NAGRA / **GLAG** **NTB:88-03**

SCHEMATIC DIAGRAM OF P1-TO-SURFACE LINE HYDRAULICS

OBERBAUENSTOCK	DAT.: APR. 88	A6.2



CURVE	K (m/s)	S	Ps (kPa)	BH
1	FIELD DATA			
9	1e-11	1e-3	215	incl
10	1e-12	1e-5	215	incl
11	1e-12	1e-7	215	incl
12	1e-11	1e-5	215	incl

NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A6.3

EXAMPLE SIMULATION - - HVB/48.6D

A7. APPENDIX A7: INTERVAL HVB/52.7D

This interval was tested using a double straddle packer assembly with a length of 5.1 m. The upper and lower packer seats were at 50.0 m and 55.1 m, respectively. Testing details are included in NIB 88-02, Section G.

A7.1 HYDROGEOLOGICAL SETTING

The interval consisted of highly fractured grey marlstone. Fractures were generally filled or partly filled with apertures from less than 2 mm to 12 mm. RQD varied from 30 to 65 percent.

This interval was the third and final detailed test conducted within the 48.6D screening interval. Packer seats were selected, in part, to cover the borehole enlargement at 53 m.

A7.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 28.6D, 48.6D, 69.6D, and 78.9D,
5. Changing of straddle, Casing Test 1, run-in of the testing equipment, and,
6. Detailed tests 42.5D, 47.6D.

Potential inflow conditions lasted for about 322 hours.

A7.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A7.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Deflation	DEF

A7.3.1 Interval Response

Testing began with a 43 minute compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 196 minutes and the pressure decreased slowly by about 70 kPa indicating the zone was likely tight. Pi1 was done using the FAV and recovered about 85 percent in 320 minutes.

Pi2 was done using the HVT and recovered by less than 10 percent in almost 700 minutes. The response of both pulse tests indicated a low permeability. The testing was terminated at the end of the Pi2 event when the pressure was 1042 kPa.

A7.3.2 Annulus Response

The pressure remained stable at between 576 and 578 kPa during the testing period.

A7.3.3 Bottomhole Response

The P1-line surface valve remained closed during the entire testing period.

The initial P1 pressure increase was in response to packer squeeze during inflation. The pressure decayed consistently thereafter.

A7.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 38 kPa over the testing period.

A7.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.6°C and 17.2°C. The surface probe temperature remained at 19.8°C.

A7.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

A7.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Despite some irregularities in both the pulse tests, their response characteristics indicated that the zone had relatively low conductivity.

The Pi1 event responded faster in the first few minutes than later. The match with the type curves was not good. This suggested the inner boundary conditions were
not as assumed in the analysis.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A7.2. The response of the HVT injection test (Pi2) was not separated from the earlier testing recognizing that attempts at bounding these data would be reasonable due to the small percentage recovery.

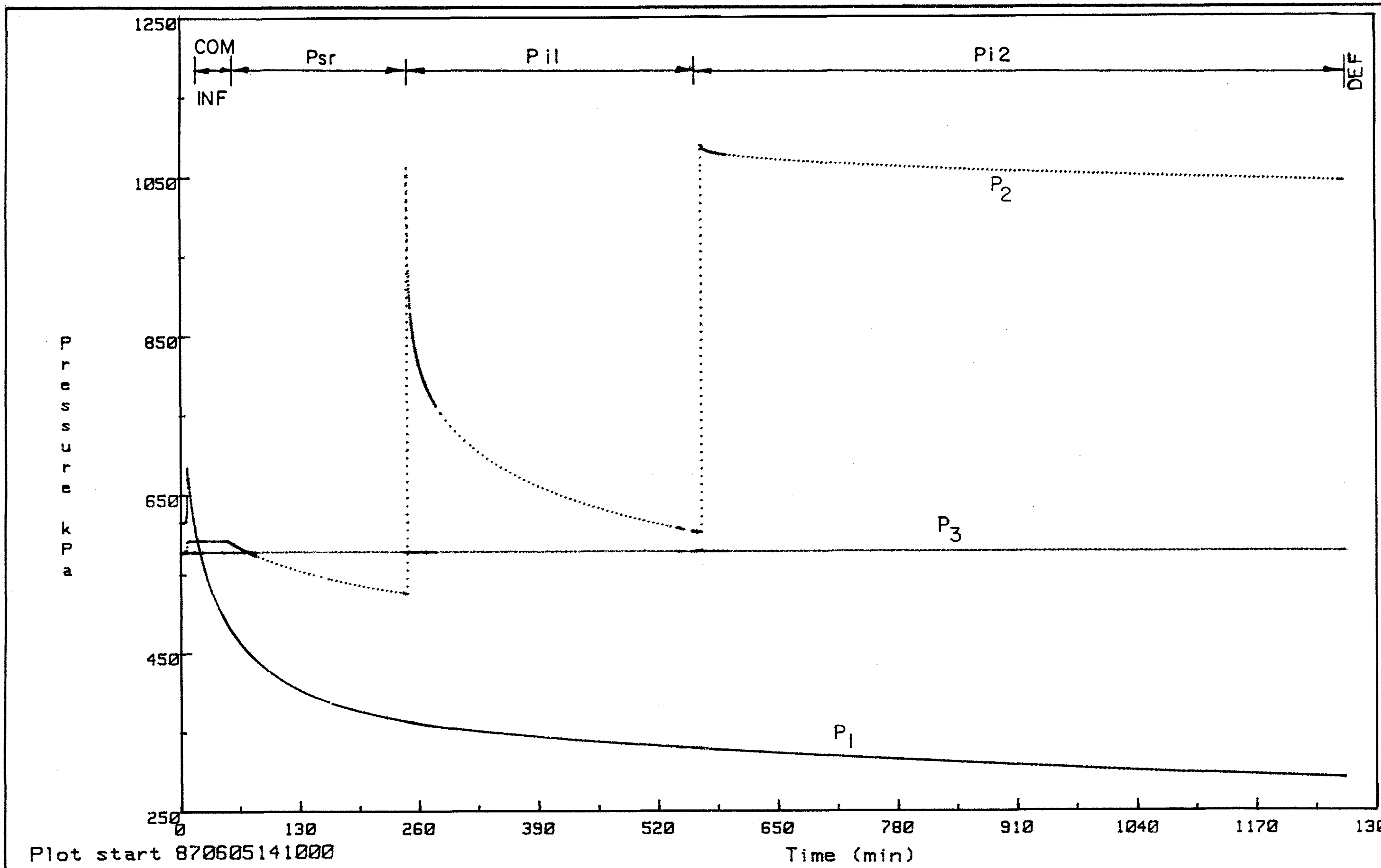
No value of static pressure could be determined from the testing since the zone was too tight. A value of 150 kPa was selected initially based on the assumed trend of pressures in the borehole. Sensitivity analyses were done over the range from 140 to 450 kPa. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

A7.4.2 Results

Borehole history pressures were generally between 550 and 650 kPa. Testing that resulted in bottomhole pressure decreases also affected the interval. In these instances, pressures dropped as low as 300 kPa. The drilling and prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined. The value at the end of the Psr event was 525 kPA. A static pressure value of between 150 to 450 kPa is possible.

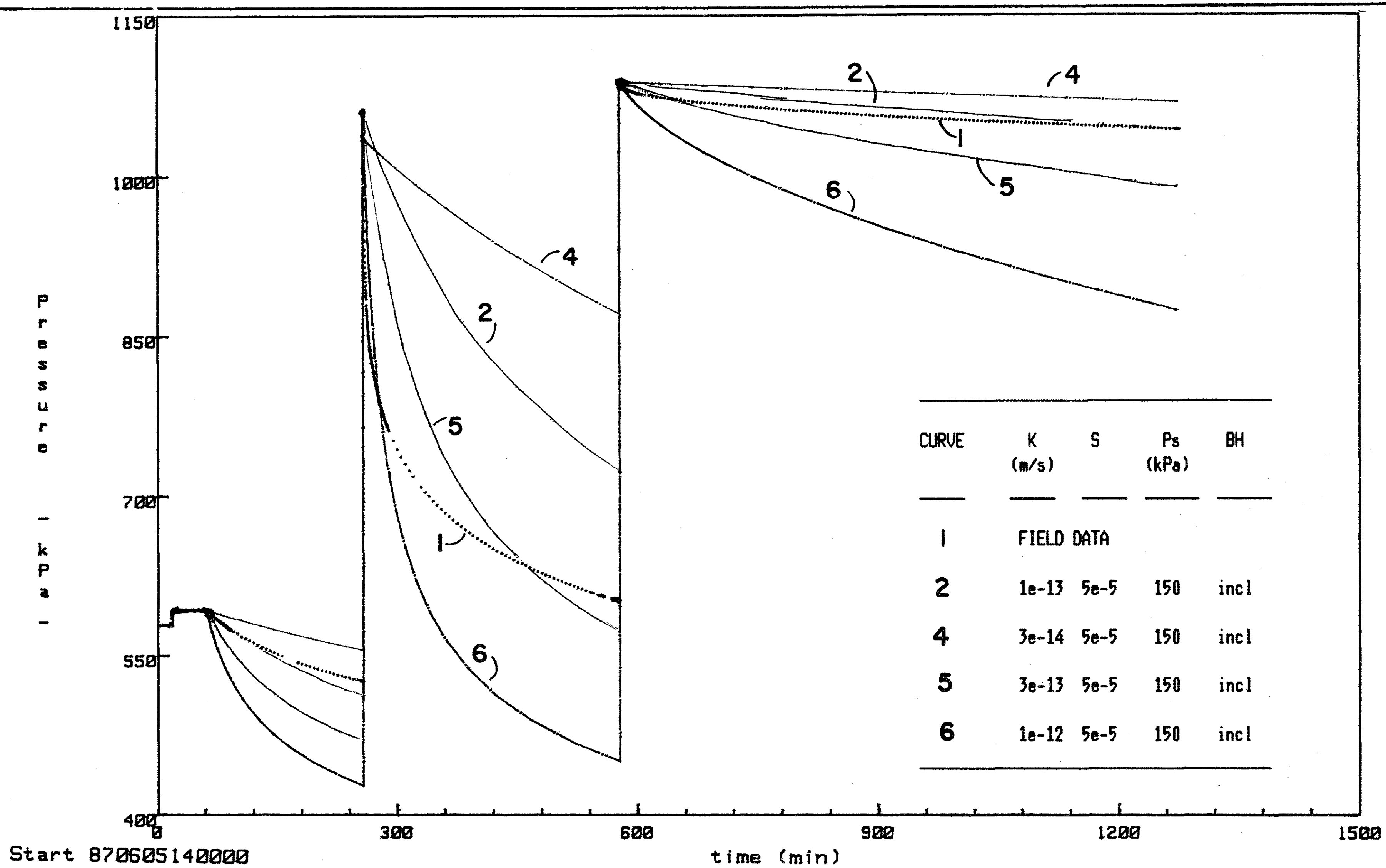
The data were able to be bounded with a hydraulic conductivity between 1e-13 m/s and 1e-12 m/s at a storativity between 5e-7 and 5e-4. The early time data of the Pi1 event responded faster than any of the simulations. Assigning a conductivity value of less than 1e-12 m/s was reasonable for the interval response over the range of possible storativity values and the uncertainty in the Ps value.

The anomalous early time Pi1 response may have been the result of a gas in the closed chamber, other packer compliance effects or unaccounted for conditions that affected the wellbore storage conditions.



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A7.1

PRESSURE SEQUENCE PLOT - HVB/52.7D



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A7.2

EXAMPLE SIMULATION - - HVB/52.7D

A8. APPENDIX A8: INTERVAL HVB/69.6D

This interval was tested using a double straddle packer assembly with a length of 20.0 m. The upper and lower packer seats were at 59.6 m and 79.6 m, respectively. Testing details are included in NIB 88-02, Section C.

A8.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey marlstone. Fractures were primarily along planes and generally filled or partly filled. Apertures ranged from 1 mm to 10 mm. RQD varied from 50 to 90 percent.

This interval was the third test and the third of four screening tests conducted in the borehole. Packer seats were selected to cover the 20 m section of the borehole immediately beneath the HVB/48.6D interval. Caliper anomalies showed deviations to about 100 mm.

A8.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Testing HVB/28.6D screening interval, and,
5. Testing HVB/48.6D screening interval.

Potential inflow conditions lasted for about 180 hours.

A8.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A8.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Slug withdrawal 1	Sw1
6. Pressure recovery 1	Pr1
7. Deflation	DEF

A8.3.1 Interval Response

Testing began with a 1 hour compliance period during which time the fluid level remained constant at the top of the tubing. The Psr lasted 638 minutes and was extended to observe the interval response towards a static pressure. The pressure decreased by 310 kPa and was still decreasing when the event was terminated with a final pressure of 375 kPa.

Pi1 was done using the FAV and recovered by about 85 percent after a period of 112 minutes.

Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 192 kPa at the start of Sw1. An underpressure was used to see if fluid would flow up into the tubing. Flow did occur and the interval pressure increased by 6 kPa during 89 minutes. At this time, the FAV was closed and the final pressure buildup was monitored.

Pr1 lasted about 11 hours during which time the pressure increased from 198 to 249 kPa. The pressure was increasing slowly at the end of Pr1.

A8.3.2 Annulus Response

The pressure remained stable at about 665 kPa during the testing period.

A8.3.3 Bottomhole Response

The P1 surface line remained closed throughout the testing period. The P1 pressure increased in response to packer inflation (Figure A8.1, A to B) and then decayed, as expected, during compliance.

The saw-tooth step that occurs in the decay curve (Figure A8.1, Points C-D) coincides with a pressure about 100 kPa less then the pressure at which P1 was shut-in during inflation. The step is therefore believed to result from the formation of vapour pressure in the inflation line cable reel. At this point, the P1 line started to drain down into the P1 zone. The pressure response of this action is a cyclic curve as the fluid in the line travels around the reel.

At point D, the fluid level goes below the reel and starts to drop down the P1 line into the borehole. The resulting void would be filled with vapour that 'boils' out of the column of water.

Section A6.3.3 provides more detail on P1 response.

A8.3.4 Packer Pressure Response

The packer pressure decreased about 3000 kPa over the test period, from an inflation peak of 62 bars to 30 bars at deflation. This test was performed before the constant inflation pressure equipment was operational.

A8.3.5 Temperature Response

Temperatures at sensor depth remained stable between 16.7°C and 17.4°C. The surface probe temperature varied from about 18.6°C to 19.6°C.

A8.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures during drilling opposite the interval likely influenced the formation response during testing.

A8.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Pulse test data matched well with the type curves indicating a hydraulic conductivity in the range of $1e^{-12}$ m/s and a storativity of $1e^{-5}$. This was based on using a static pressure equal to that at the end of the Psr event.

The flow rate of the Sw1 event was too low to reach infinite acting radial flow conditions. Therefore, the Horner-type analyses which indicated higher conductivities were not considered accurate. However, all transient responses indicated that the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A8.2.

No value of static pressure could be determined from the testing since the zone was too tight. A value of 250 kPa was selected initially based on a knowledge of the borehole history pressures and the decreasing trend of the interval response at the end of the Pr1 event. Sensitivity analyses were done with static pressure values ranging from 150 to 255 kPA. With this low a conductivity, the sensitivity to changes on the order 100 kPa in the static pressure would be low.

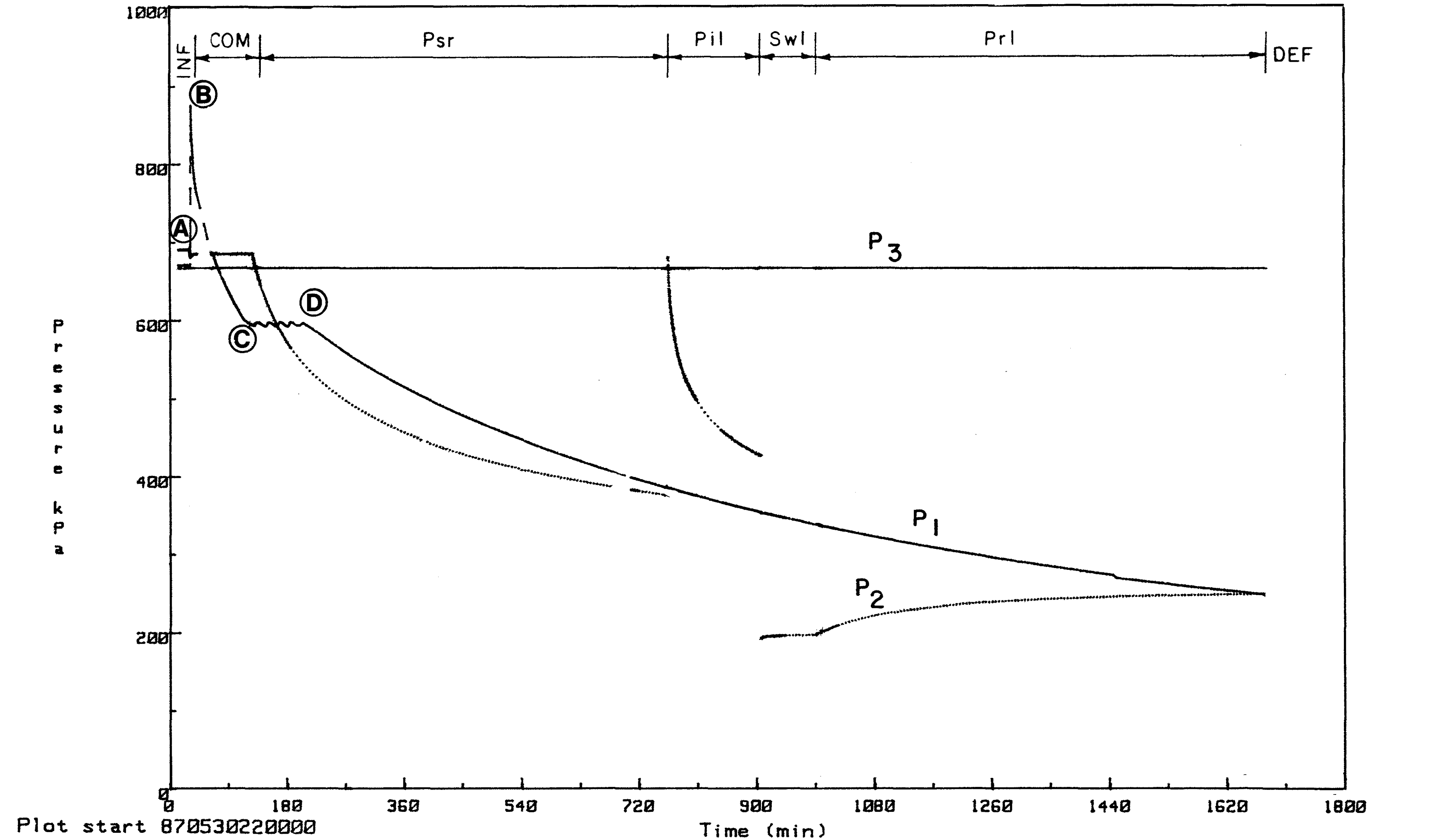
A8.4.2 Results

Borehole history pressures were in the range of 650 to 700 kPa for the 5 days of pretesting activities in the borehole. Pressures opposite the interval decreased and were from about 300 to 500 kPa during the previous HVB/28.6D and 48.6D screening tests. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

The value at the end of the Psr event was 375 kPA. The value at the end of the Pr2 event was 250 kPa and still increasing. However, this increase, based on the conductivity of the zone was likely still being influenced by the 5 days time that the fluid level in the borehole was at the level of the drilling gallery floor. A value in the range of 150 to 250 kPa is possible for the static pressure in this zone given the potential borehole history influence.

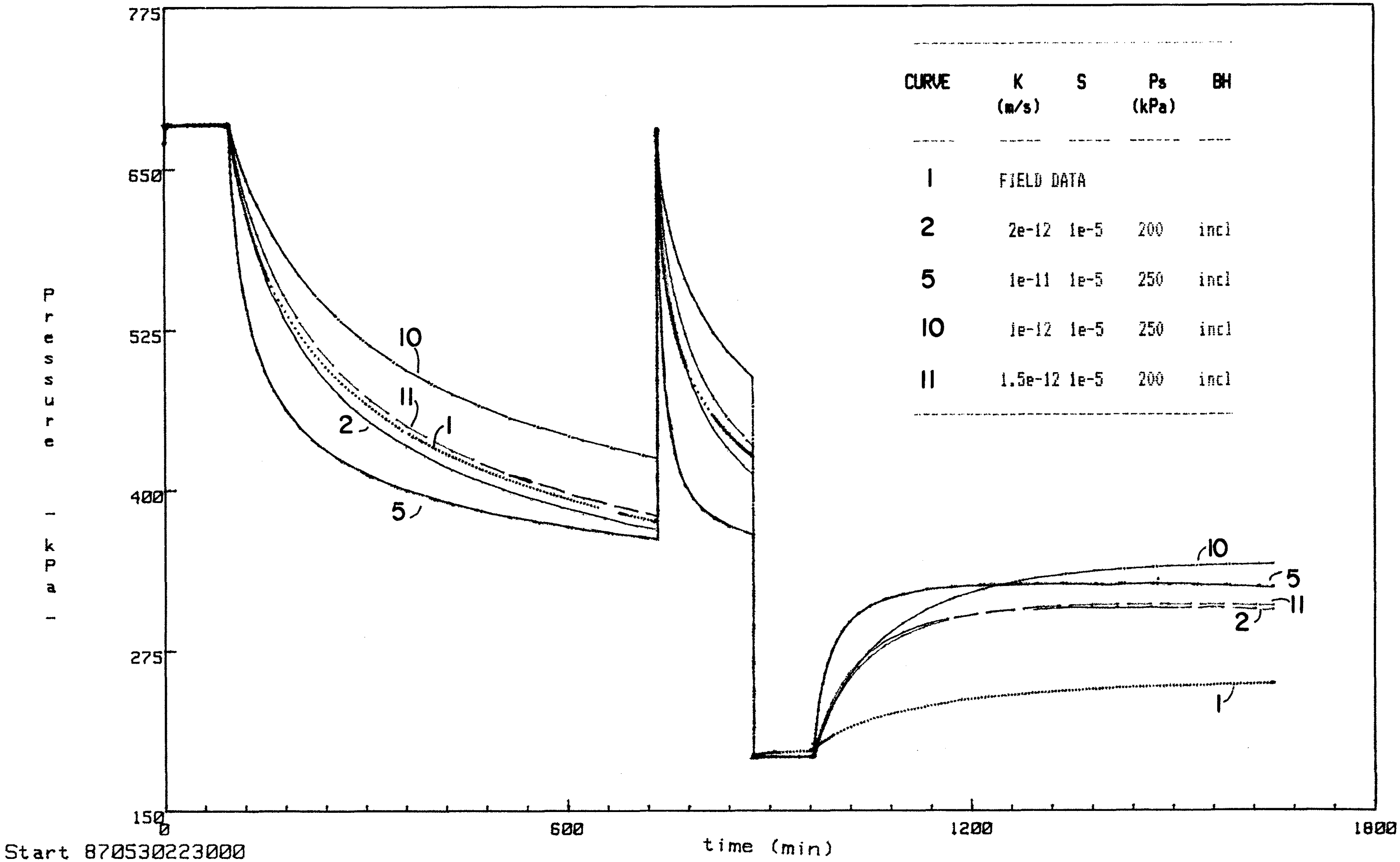
The data was not able to be bounded with with consistent parameter values. The flow during Sw1 required conductivity values on the order of 1e-9 m/s compared to values of less than 1e-11 m/s for the previous events. Therefore, the zone has been assigned a conductivity value of less than 1e-9 m/s with storativity ranging from 3e-6 to 1e-3.

Assigning such a high conductivity upper limit was done because of the flow that occurred during Sw1. Other factors such as fracture flow or a skin affect may account for the differences in response characteristics seen during all events.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A8.1

PRESSURE SEQUENCE PLOT - HVB/69.6D



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A8.2

EXAMPLE SIMULATION - - HVB/69.6D

A9. APPENDIX A9: INTERVAL HVB/74.5D

This interval was tested using a double straddle packer assembly with a length of 5.1 m. The upper and lower packer seats were at 72.0 m and 77.1 m, respectively. Testing details are included in NIB 88-02, Section H.

A9.1 HYDROGEOLOGICAL SETTING

The interval consisted of fractured grey marlstone. Fractures were generally filled or partly filled with apertures from 2 mm to 20 mm. RQD varied from 30 to 80 percent.

This interval was the fourth detailed test conducted in the HVB borehole and straddled part of both the 69.6D and 78.9D screening test intervals. Packer seats were selected to cover the borehole enlargement between 72 and 78 m.

A9.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 28.6D, 48.6D, 69.6D, and 78.9D,
5. Changing of straddle, Casing Test 1, run-in of the testing equipment, and,
6. Detailed tests 42.5D, 47.6D, and 52.7D.

Potential inflow conditions lasted for about 323 hours.

A9.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A9.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Deflation	DEF

A9.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted 158 minutes. The pressure in the interval increased and then started to decrease during Psr. This was likely in response to continued packer inflation and the fact that the interval had a very low permeability. Pi1 was done using the FAV and recovered about 90 percent in 212 minutes. The event lasted longer than planned. A problem occurred with data acquisition and the signal failed. Replacing an SC2 converter box solved the problem.

The pressure at the end of the Pi1 event was 874 kPa and was still decreasing slowly. The interval was considered to have too low a permeability to warrant performing further events and testing was terminated.

A9.3.2 Annulus Response

The pressure remained stable at about 793 kPa during the testing period.

A9.3.3 Bottomhole Response

The P1-line surface valve remained closed during the entire testing period.

The initial P1 pressure increase was in response to packer squeeze during inflation. The pressure decayed in a consistent manner after inflation to a final pressure of 525 kPa.

A9.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It increased by about 13 kPa over the testing period.

A9.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.8°C and 17.5°C. The surface probe temperature varied from 19.7°C to 20.0°C.

A9.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

A9.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. The Pi1 analysis prepared in the field for the QLR report was reviewed. The type-curve match appeared reasonable and indicated a conductivity on the order of 6e-13 m/s with a storativity of 2e-5 using an effective static pressure of 833 kpa, the end pressure of the Psr event. The response characteristics of both the Psr and Pi1 indicated that the zone had relatively low conductivity.

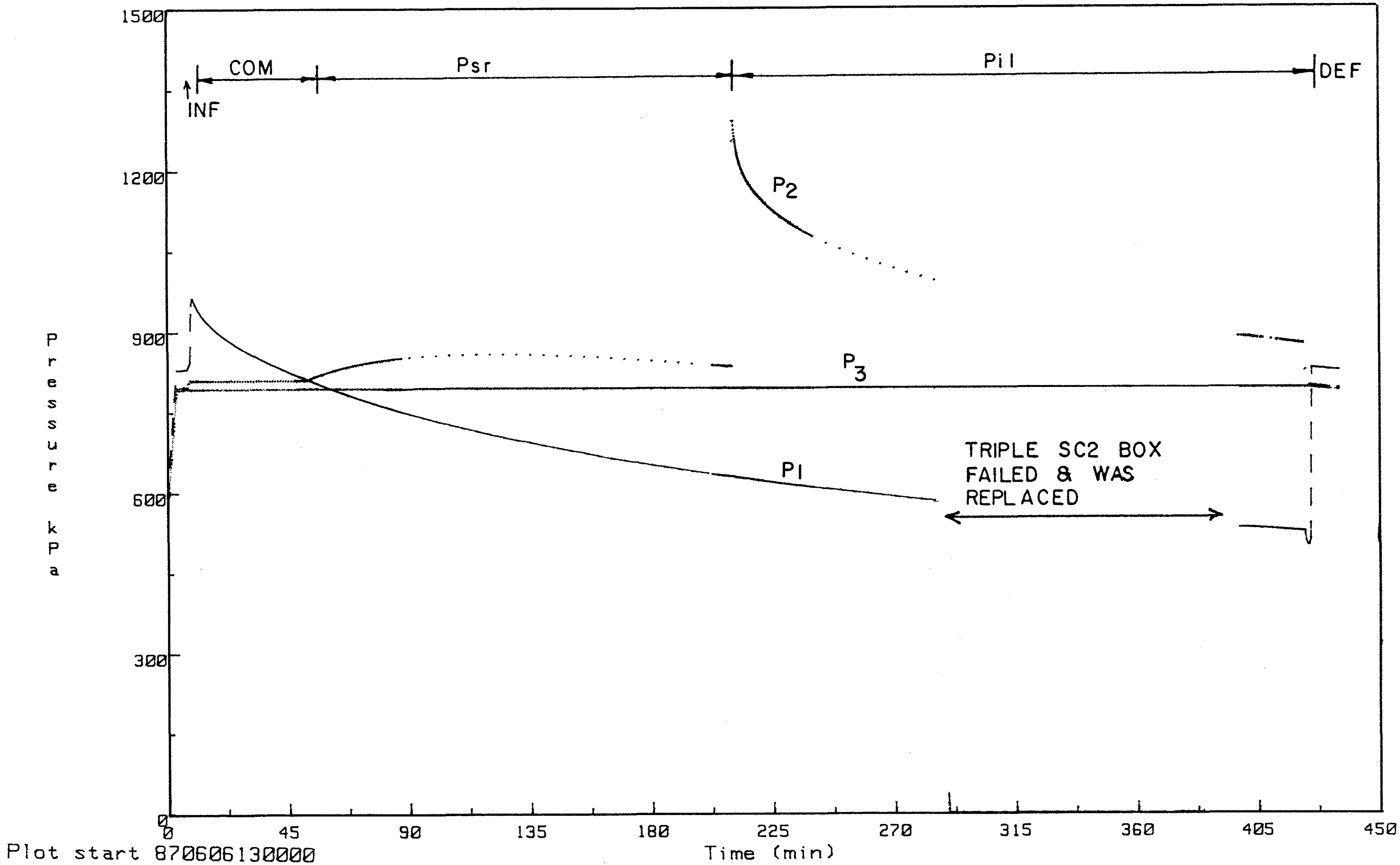
The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A9.2. The response of Psr was assigned linearly changing pressures since the increase and following decrease were suspected to be related to packer squeeze. Therefore, the only event that was bounded was Pi1.

No value of static pressure could be determined from the testing since the zone was too tight. A values of 250 kPa was used initially. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

A9.4.2 <u>Results</u>

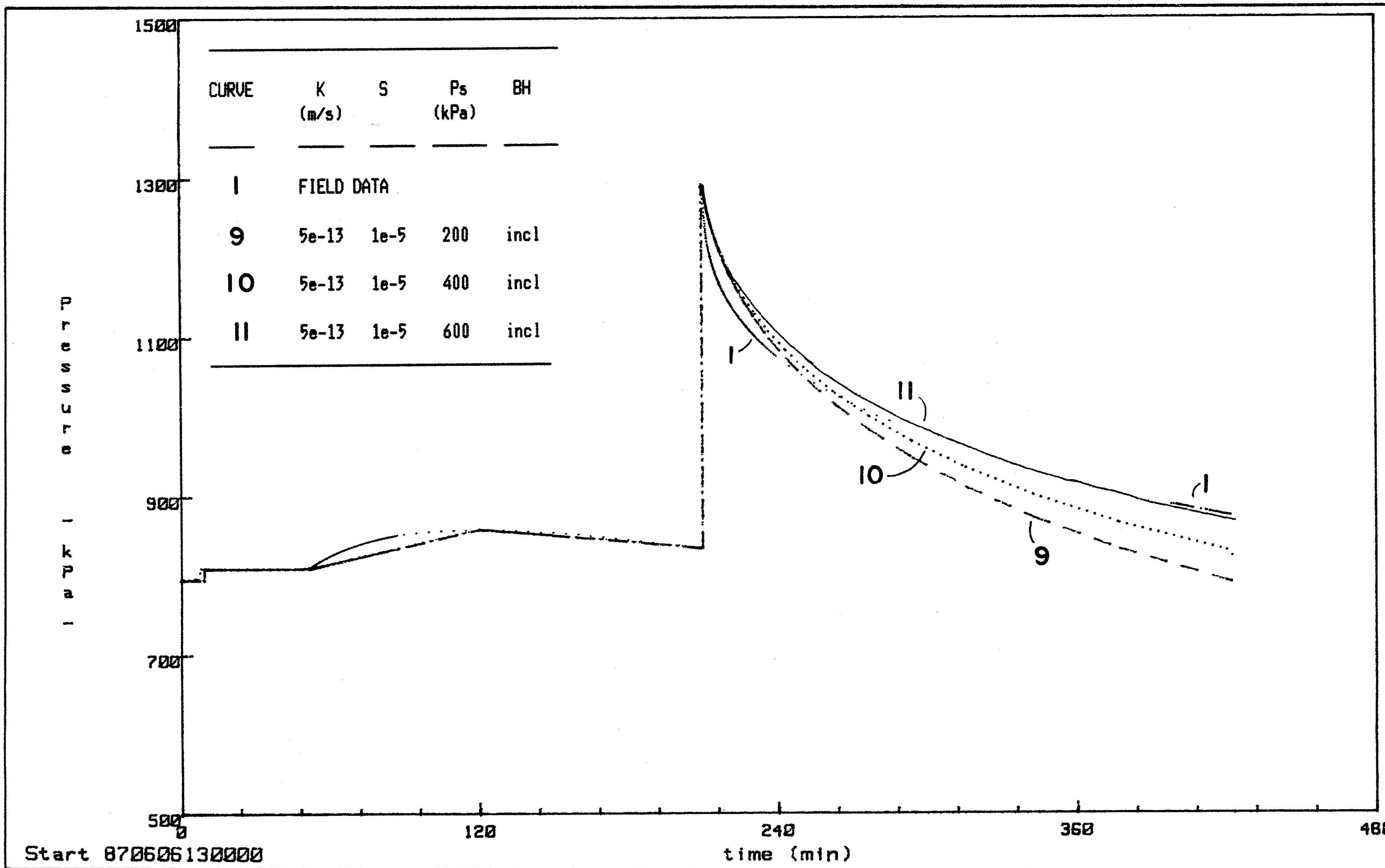
Borehole history pressures ranged from 300 to 900 kPa but was generally over 750 kPa. The drilling and prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined. Sensitivity analyses over the range of 200 and 600 kPa were done with little apparent difference (Figure A9.2).

The Pi1 data were able to be bounded with hydraulic conductivity between 5e-13 m/s and 1e-13 m/s at a storativity of between 1e-7 and 1e-3. Assigning a conductivity value of less than 5e-12 m/s was reasonable for the interval response over the range of possible storativity values and the uncertainty in the Ps value.



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A9.1

PRESSURE SEQUENCE PLOT - HVB/74.5D



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EXAMPLE SIMULATION - - HVB/74.5D

A10. APPENDIX A10: INTERVAL HVB/78.9D

This interval was tested using a double straddle packer assembly with a length of 20.0 m. The upper and lower packer seats were at 68.9 m and 88.9 m, respectively. Testing details are included in NIB 88-02, Section D.

A10.1 HYDROGEOLOGICAL SETTING

The interval consisted of grey marlstone. Fractures were generally filled or partly filled. Apertures ranged from less than 1 mm to 10 mm. RQD varied from 30 to 90 percent.

This interval was the fourth test and the fourth and last screening test conducted in the borehole. Conditions of the borehole wall resulted in the fact that this interval was shallower than was originally planned. As a result, it straddled part of the HVB/69.6 interval.

A10.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Testing HVB/28.6D screening interval,
5. Testing HVB/48.6D screening interval, and,
6. Testing HVB/69.6D screening interval,

Potential inflow conditions lasted for about 200 hours.

A10.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure A10.1, included:

1.	Inflation	INF
2	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
6.	Pulse injection 2	Pi2
7.	Deflation	DEF

A10.3.1 Interval Response

Testing began with an 84 minute compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 9 hours and the pressure decreased consistently by 407 kPa to 362 kPa and was still dropping at the end of the event. Pi1 was done using the FAV and had recovered by about 98 percent in 346 minutes. Both the Psr and Pi1 events had similar response patterns. The length of the Pi1 event was increased to monitor the recovery towards a static pressure.

A second pulse injection test was done using the surface HVT as the shut-in volume. It recovered about 20 percent to a final pressure of 730 kPa and the testing was terminated after about 8 hours of monitoring during this recovery. A leak may have occurred in the line between the tank and the wellhead thereby affecting the response. In retrospect, the Pi2 event provided little useful information about the interval due to the possible leak and the hydraulics associated with testing using the HVT.

A10.3.2 Annulus Response

The pressure remained stable at about 757 kPa during the testing period.

A10.3.3 Bottomhole Response

The P1 line valve was opened at the end of inflation. The P1 pressure had a cyclic response during compliance and the first part of the Psr event. Thereafter, it decreased in a consistent manner as the fluid level dropped under atmospheric conditions in the line.

The final pressure was 411 kPa and was still decreasing.

Section A6.3.3 provides more detail on the P1 response.

A10.3.4 Packer Pressure Response

The packer pressure was shut-in after inflation. It decreased about 1200 kPa during the first 45 minutes testing. It was increased by about 1900 kPa and decreased an additional 2050 kPa over the remaining testing.

A10.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.8°C and 17.1°C after the start of compliance. The surface probe temperature varied from 18.6°C to 19.7°C.

A10.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures during drilling opposite the interval likely influenced the formation response during testing.

A10.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. THe Pi2 event result was discounted. The Pi1 event data matched well with the type curves although the initial instantaneous condition was not strictly met. All responses indicated that the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig A10.2.

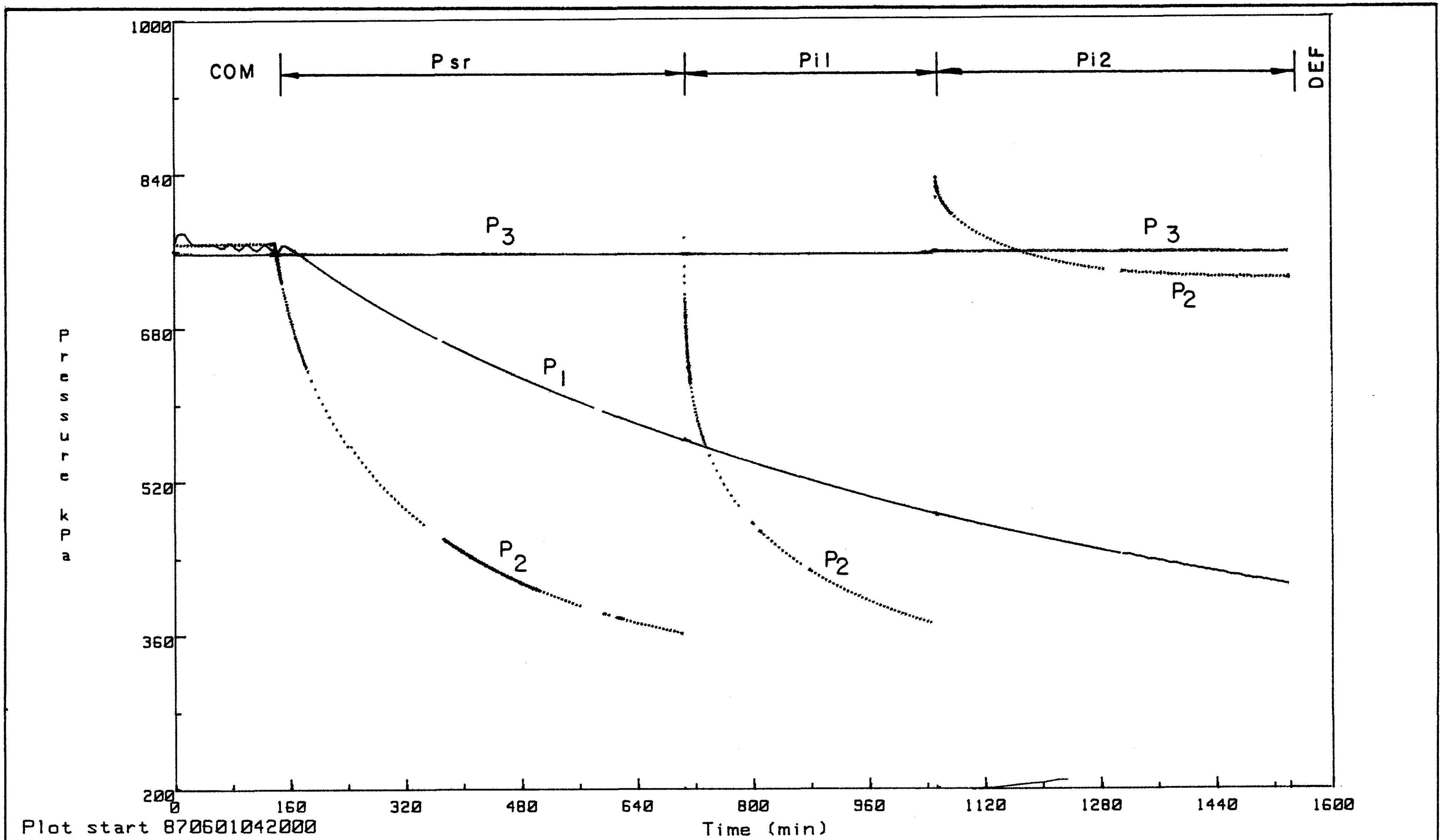
No value of static pressure could be determined from the testing since the zone was too tight. A value of 250 kPa was selected initially based on a knowledge of the borehole history pressures and the decreasing trend of the interval response at the end of the Psr event when it had reached 321 kPa and was still decreasing. At the same time, it was recognized that with this low a conductivity, the sensitivity to changes on the order of 100 to 200 kPa in the static pressure would be low.

A10.4.2 Results

Borehole history pressures were in the range of 400 to 800 kPa prior to testing and over 750 kPa most of the time. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

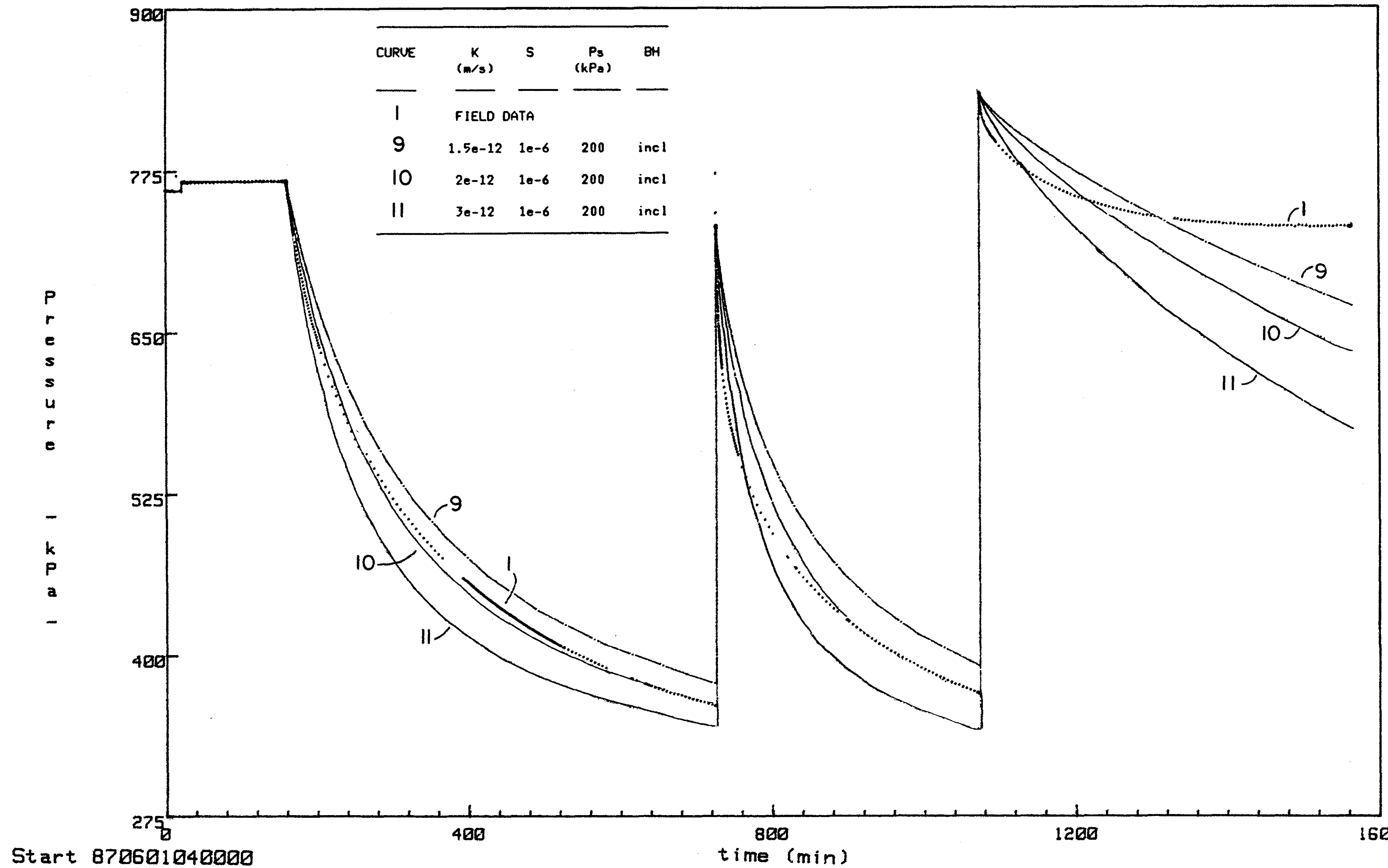
The value at the end of the Psr event was 362 kPA. The value at the end of the Pr2 event was 370 kPa and was still decreasing. These trends, as seen in Figure A10.1, indicate the pressure was likely to go below 300 kPa. The decrease, based on the conductivity of the zone was likely still being influenced by the borehole history. A value in the range of 200 to 300 kPa is possible for the static pressure in this zone. Sensitivity analyses done at values of 350 kPa did not match or bound the data well.

The data was able to be bounded with hydraulic conductivity between 1e-12 m/s and 3e-12 m/s at storativities ranging from 1e-6 to 1e-3. Assigning a conductivity value of less than 5e-12 m/s is reasonable for the interval response over the range of possible storativity values and the uncertainty in the Ps value.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	A10.1

PRESSURE SEQUENCE PLOT - HVB/78.9D



NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | A10.2

EXAMPLE SIMULATION - - HVB/78.9D

APPENDIX B:

HGB INTERVAL SUMMARIES

B1. APPENDIX B1: INTERVAL HGB/23.1D

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 19.8 m and 26.4 m along the inclined borehole, respectively. This corresponded to true vertical depths of 14.6 and 19.4 m, respectively. The P2 transducer was at a true vertical depth of 12.8 m. Testing details are included in NIB 88-03, Section J.

B1.1 HYDROGEOLOGICAL SETTING

The interval consisted of a grey, finely-laminated, calcareous marlstone. The upper 2 m of the interval were highly fractured and jointed. RQD varied from 75 to 100 percent.

This interval was the second and last detailed test conducted above the HGB/42.5D screening test interval. Packer seats were selected to cover half the borehole that had not previously been tested. The caliper log indicated enlargement to 106 mm at 20.5 m, just below the casing. The bottom of the upper packer was located in casing, 0.3 m above the shoe.

The lack of annulus fluid level change in previous tests suggested the interval would be tight.

B1.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 82.5D, 62.5D, and 42.5D,
5. Changing of straddle, run-in of equipment, and,
6. Detailed tests 76.3D, 83.3D, 68.7D, 62.1D, 55.5D1, and 29.7D.

Potential inflow conditions lasted for about 463 hours.

B1.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B1.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Deflation	DEF

B1.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 6 hours. The pressure increased by 11 kPa to 234 kPa, likely in response to continued packer squeeze in the relatively tight zone.

Pi1 was done using the FAV and recovered by about 70 percent in about 6 hours and was terminated at a pressure of 337 kPa. The late time data suggested a higher extrapolated pressure than had been expected. A second pulse test. Pi2, was done using a higher overpressure. It lasted 167 minutes and recovered to about 50 percent of the Pi1 end pressure.

Testing was terminated considering that both pulse tests had consistent results indicating the zone had a relatively low permeability and did not warrant additional testing.

B1.3.2 Annulus Response

The pressure remained stable at about 218 kPa during the testing period.

B1.3.3 Bottomhole Response

The P1-line surface valve remained closed during the inflation and was opened just after beginning the Psr event.

The initial P1 pressure increase was in response to packer squeeze during inflation. The pressure at the time just before the valve was opened was 58 kPa. The pressure fluctuated during testing and increased to about 74 kPA at the end of testing.

The below atmospheric pressures may be the result of water vapour pressures being formed in the line as a result of the falling liquid level in the hydraulic pathways to below the bottom packer.

B1.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 70 kPa over the 16 hour testing period.

B1.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.3°C and 17.1°C. The surface probe temperature varied from 19.9°C to 20.7°C.

B1.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B1.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Both the pulse tests had responses in the first two to three minutes, that were faster than the rest of the data. Accordingly, the type curve matches reflected only the early time response and were not indicative of the late time data which depicted a lower conductivity. The late time data however, along with the pressure rise during Psr indicated the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B1.2. The Psr pressure increase was assigned several step-wise increasing pressures to simulate the artificial response from the packer squeeze. The rapid falloff at the beginning of both pulse tests was not bounded. Instead, it was assumed that this condition was due to a different inner boundary or wellbore storage condition. Attempts concentrated on trying to bound the general shape of the remaining falloff.

No value of static pressure could be determined from the testing since the zone was too tight. A value of 95 kPa was selected based on the assumed trend of pressures in the borehole. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

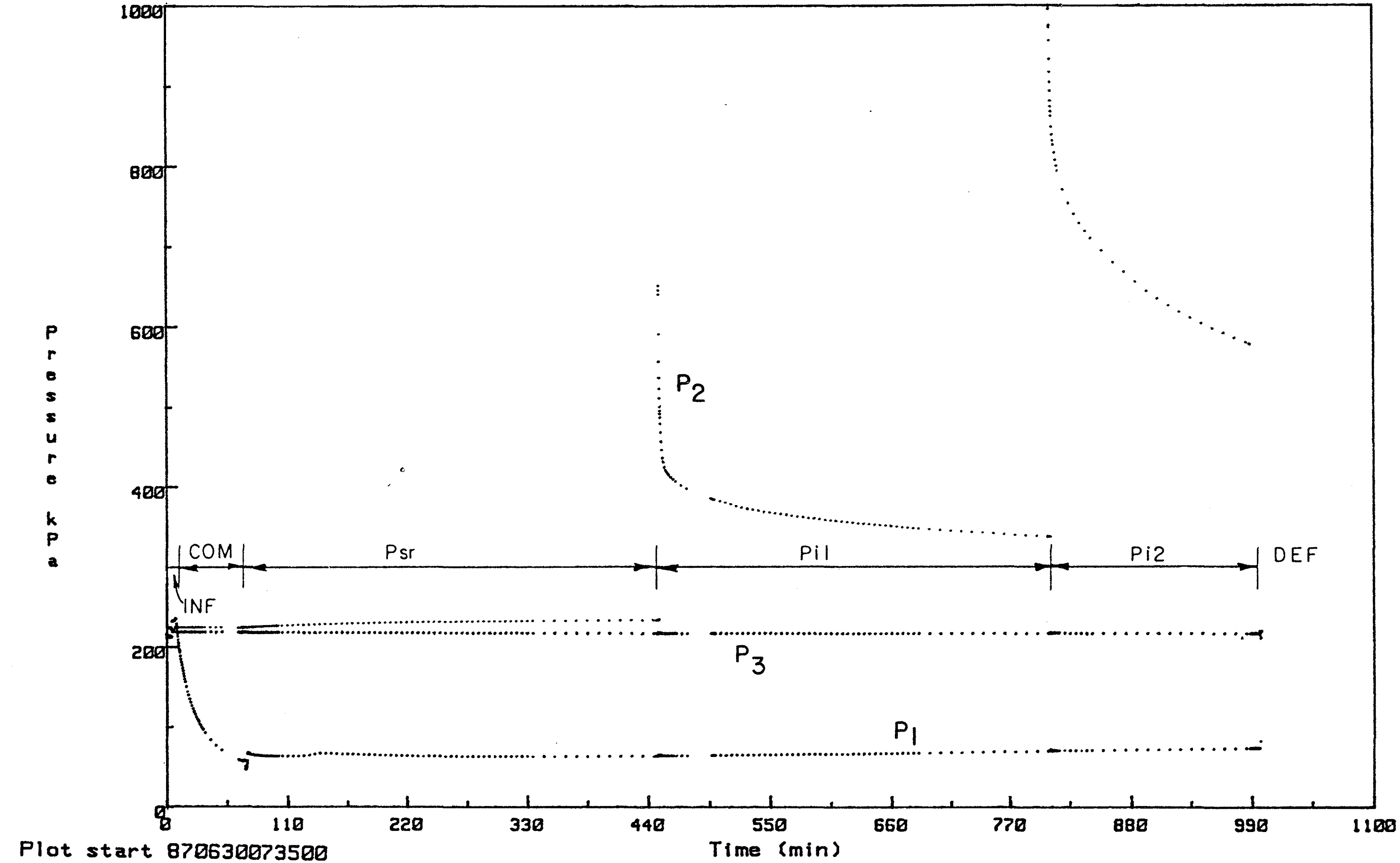
B1.4.2 Results

Borehole history pressures were between 225 and 250 kPa for most of the 19 day borehole history period. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

The pressure value at the end of the Psr event was not representative of the interval due to the packer squeeze. A value of 95 kPa was used in the simulations assuming that part of the zone may have been unsaturated prior to drilling. However, this was an assumption made at the time of the analyses based on the trend in the more permeable zones in the rest of the borehole. Similar responses to those obtained could have been generated with pressures in the range of 150 kPa.

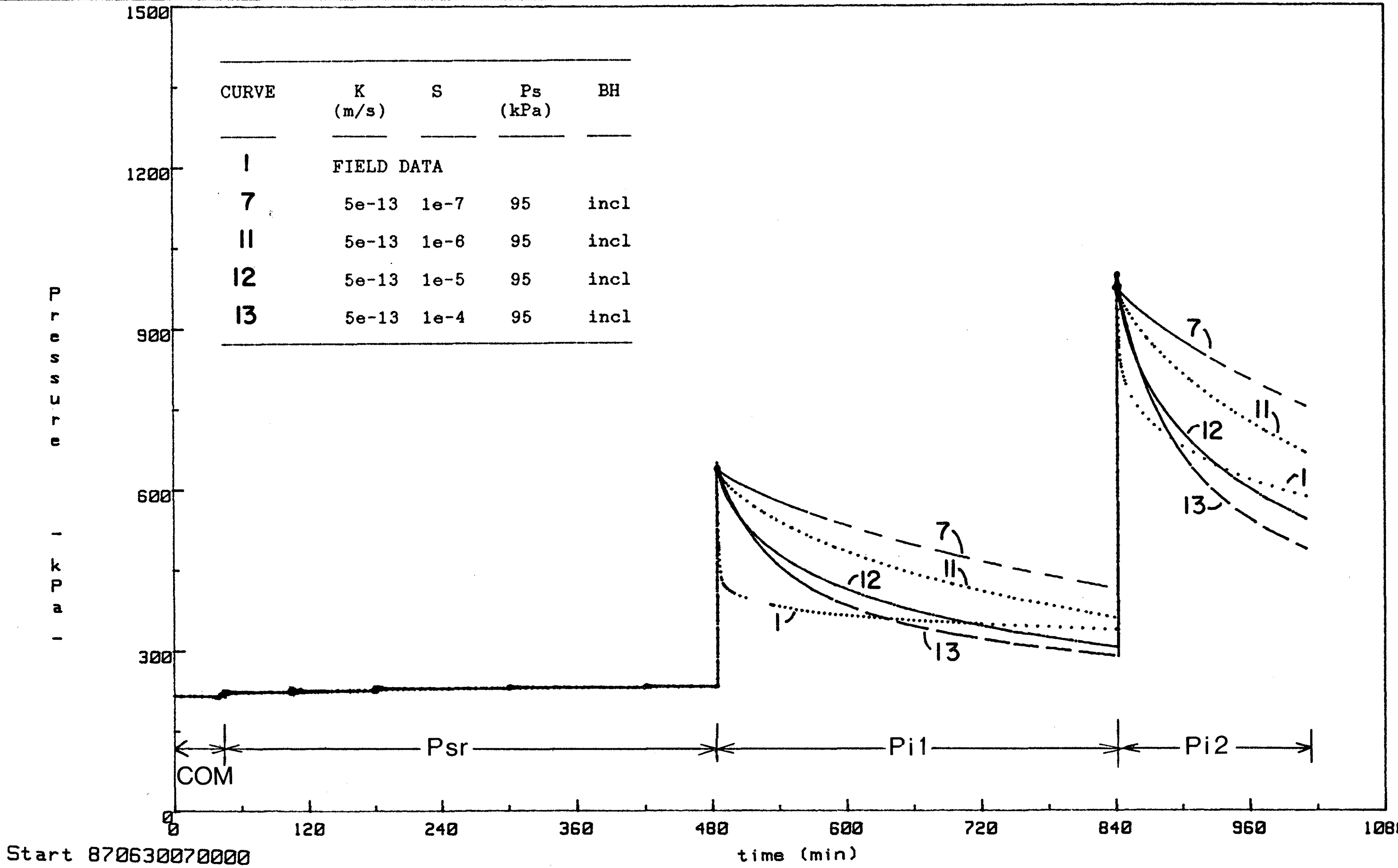
The data were not well bounded. The early time responses could have been analyzed in more detail, and assigned pressure steps to match the real data. Concentration then would have been to match the later responses of both pulse tests. However, this was not done due to time constraints for the analysis at this stage of reporting. In general, except for the early time data, the two pulse tests suggest hydraulic conductivity should be between 5e-13 m/s and 1e-12 m/s at storativity between 1e-6 and 1e-4. This is also consistent with the response during the Psr event.

The anomalous early time pulse test responses may have been the result of a gas in the closed chamber or packer compliance, or other, different wellbore storage conditions such as a larger wellbore volume.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B1.1

PRESSURE SEQUENCE PLOT - HGB/23.1D



CURVE	K (m/s)	S	Ps (kPa)	BH
1	FIELD DATA			
7	5e-13	1e-7	95	incl
11	5e-13	1e-6	95	incl
12	5e-13	1e-5	95	incl
13	5e-13	1e-4	95	incl

NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | B1.2

EXAMPLE SIMULATION - - HGB/23.1D

B2. APPENDIX B2: INTERVAL HGB/29.7D

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 26.4 m and 33.0 m along the inclined borehole, respectively. This corresponded to true vertical depths of 19.4 and 24.2 m, respectively. The P2 transducer was at a true vertical depth of 17.6 m. Testing details are included in NIB 88-03, Section I.

B2.1 HYDROGEOLOGICAL SETTING

The interval consisted of a grey, homogeneous, fine-grained calcareous marlstone. Several small fractures were reported. RQD varied from 75 to 100 percent.

This interval was the first of two detailed tests conducted above the HGB/42.5D screening test interval. Packer seats were selected to cover half the borehole
that had not previously been tested. The caliper log varied from 97 to 100 mm.

The lack of annulus fluid level change in previous tests suggested the interval would be tight.

B2.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 82.5D, 62.5D, and 42.5D,
5. Changing of straddle, run-in of equipment, and,
6. Detailed tests 76.3D, 83.3D, 68.7D, 62.1D, and 55.5D1.

Potential inflow conditions lasted for about 376 hours.

B2.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B2.1, included:

1.	Inflation	INF
2	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1

5. Pulse injection 2 Pi2
6. Deflation DEF

B2.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 3 hours. The pressure increased by 16 kPa to 234 kPa, likely in response to continued packer squeeze in the relatively tight zone.

Pi1 was done using the FAV and recovered by about 70 percent in about 5 hours and was terminated at a pressure of 426 kPa. The late time data suggested a higher extrapolated pressure than had been expected. A second pulse test, Pi2, was done using a higher overpressure. It lasted about 6 hours and recovered to about 70 percent of the Pi1 end pressure.

Testing was terminated considering that both pulse tests had consistent results indicating the zone had a relatively low permeability and did not warrant additional testing.

B2.3.2 Annulus Response

The pressure remained stable at about 265 kPa during the testing period.

B2.3.3 Bottomhole Response

The P1-line surface valve remained closed during the inflation and was opened just before beginning the Psr event.

The initial P1 small pressure increase was in response to packer squeeze during inflation. The pressure at the time just before the valve was opened was less than 60 kPa. The pressure appeared to be oscillating during the Psr and Pi1 events. Itincreased and fell in a series of 9 steps during testing. The final pressure was 59 kPa. Section A6.3.3 provides more detail on the P1 response.

B2.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 48 kPa over the 16 hour testing period.

B2.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 15.7°C and 16.7°C. The surface probe temperature varied from 20.4°C to 20.5°C.

B2.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B2.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Both the pulse tests had responses in the first five to ten minutes, that were faster than the rest of the data. Accordingly, the type curve matches reflected only the early time response and were not indicative of the late time data. Even the early time data, however, indicated conductivity values on the order of 1e-13 m/s, consistent with the pressure rise due to packer squeeze during Psr. Results indicated the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B2.2. The Psr pressure increase was assigned several step-wise increasing pressures to simulate the artificial response from the packer squeeze. The more rapid falloff at the beginning of both pulse tests was not well bounded. Attempts concentrated on trying to bound the general shape of the falloff.

No value of static pressure could be determined from the testing since the zone was too tight. Values of 95 to 125 kPa were used in the simulations based on the assumed trend of pressures in the borehole. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

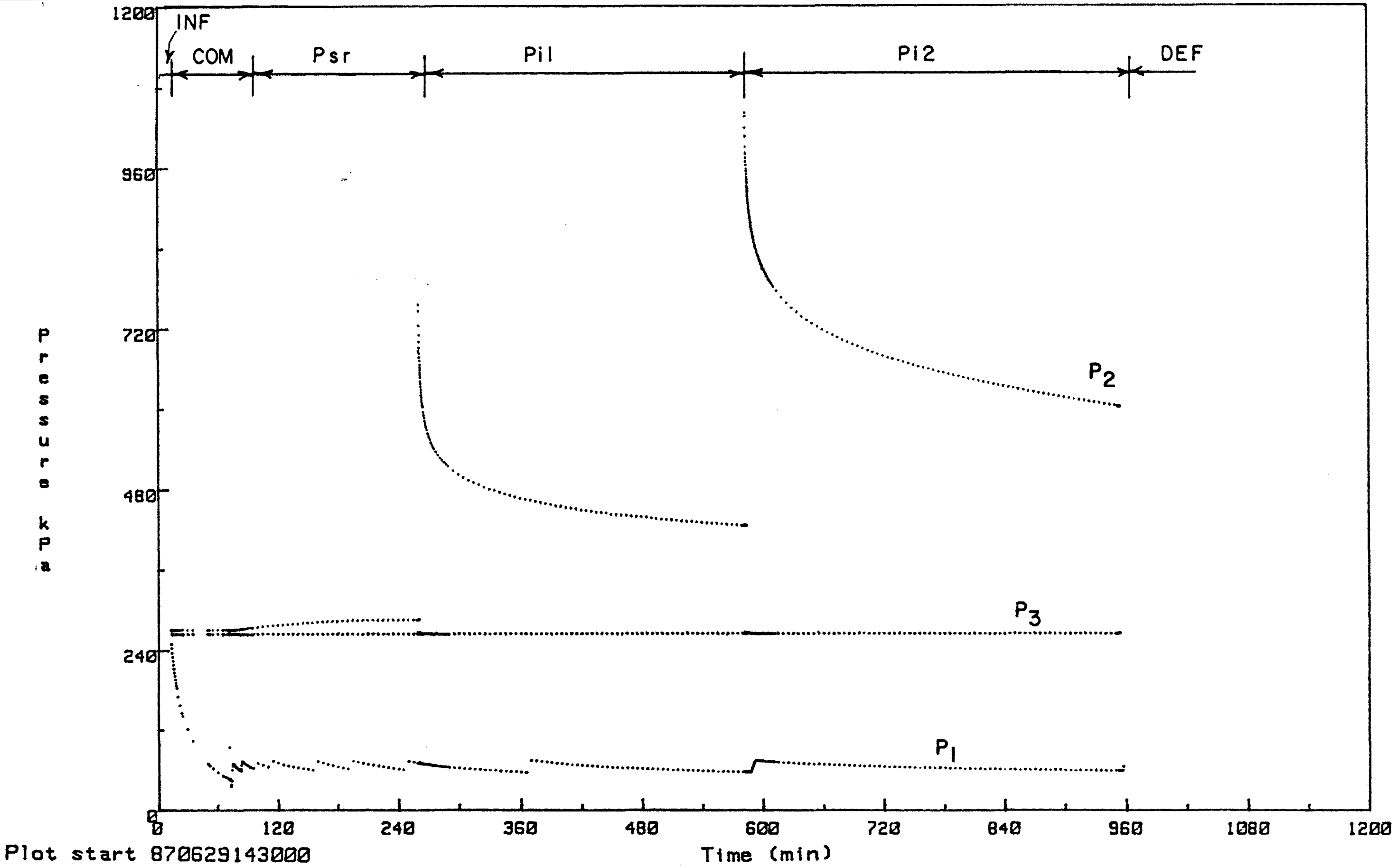
B2.4.2 Results

Borehole history pressures were between 275 and 300 kPa for most of the 16 day borehole history period. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

The pressure value at the end of the Psr event was not representative of the interval due to the packer squeeze. The value of 95 kPa used in the simulations implies that part of the zone may have been unsaturated prior to drilling. However, this was an assumption made at the time of the analyses based on the trend in the more permeable zones in the rest of the borehole. Virtually identical responses to those obtained with 95 kPa were obtained with 125 kPa.

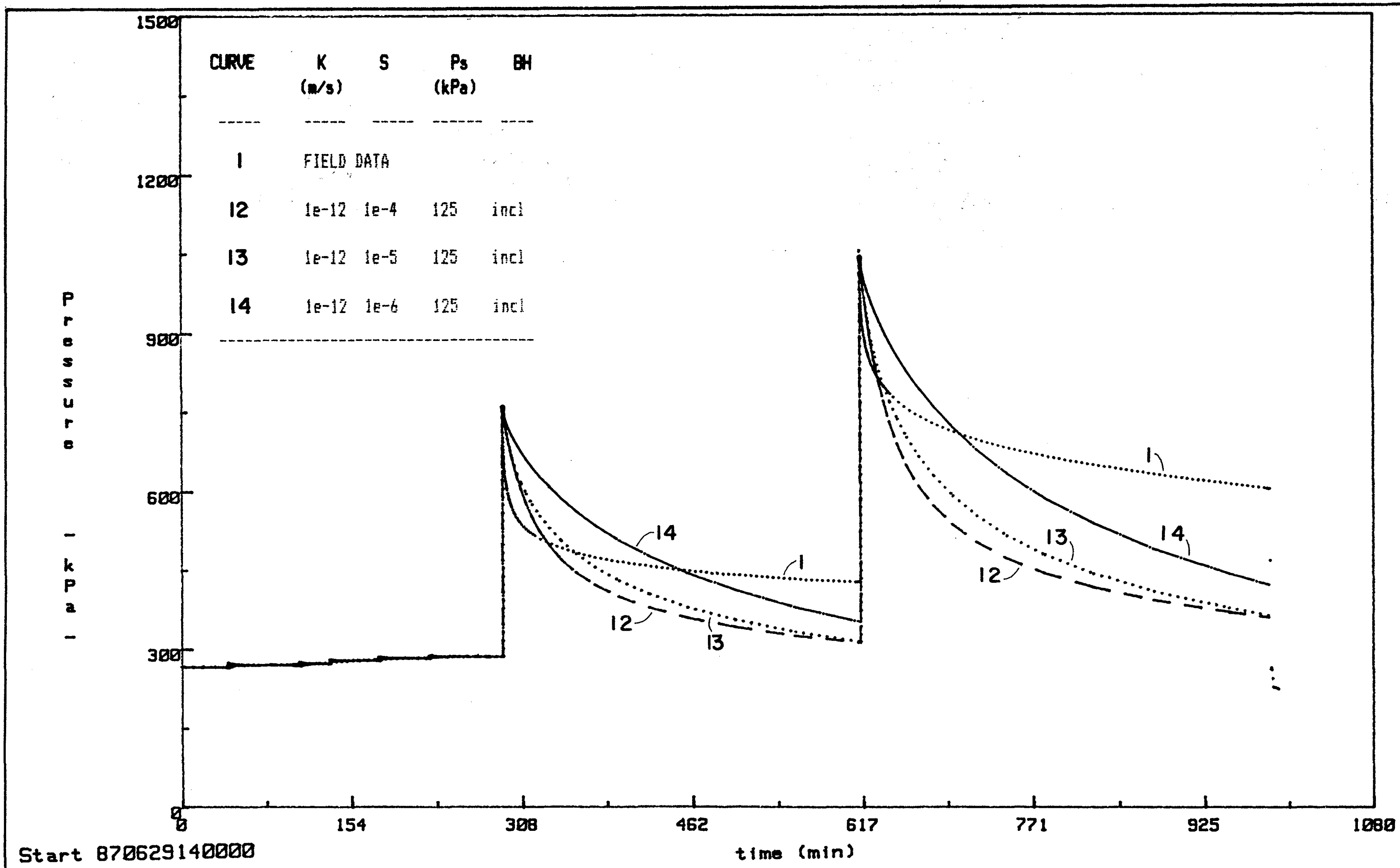
Except for the first few minutes of the pulse tests, the data were bounded. The early time responses could have been analyzed in more detail, and assigned pressure steps to match the real data. Concentration then should have been to match the later responses of both pulse tests. However, this was not done due to time constraints for the analysis at this stage of reporting. In general, except for the early time data, the two pulse tests suggest hydraulic conductivity should be between 1e-13 m/s and 1e-12 m/s at storativity between 1e-6 and 1e-4. This is also consistent with the response during the Psr event.

The anomalous early time pulse test responses may have been the result of a gas in the closed chamber or packer compliance, or other, different wellbore storage conditions such as a larger wellbore volume.



NAGRA / GLAG NTB:88-03	OBERBAUENSTOCK	DAT.: APR. 88	B2.1

PRESSURE SEQUENCE PLOT - HGB/29.7D



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B2.2

EXAMPLE SIMULATION - - HGB/29.7D

B3. APPENDIX B3: INTERVAL HGB/42.5D

This interval was tested using a double straddle packer assembly with a length of 19.0 m. The upper and lower packer seats were at lengths of 33.0 m and 52.0 m along the inclined borehole, respectively. This corresponded to vertical depths of 24.2 and 38.4 m, respectively. The P2 transducer was at a true vertical depth of 22.4 m. Testing details are included in NIB 88-03, Section C.

B3.1 HYDROGEOLOGICAL SETTING

The interval consisted of a massive grey clayey marlstone. Minor fractures were both infilled with calcite or open and fluid bearing. RQD varied from 60 to 100 percent.

This interval was the third of three screening tests done in HGB. Packer seats were selected to cover the zone above the 62.5 screening interval.

The lack of annulus fluid level change in previous two tests suggested the interval would be tight.

B3.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 82.5D and 62.5D.

Potential inflow conditions lasted for about 173 hours.

B3.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B3.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Deflation	DEF

B3.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 100 minutes. The pressure increased by 5 kPa to 291 kPa, likely in response to continued packer squeeze in the relatively tight zone.

Pi1 was done using the FAV and recovered by about 90 percent in 206 minutes and was terminated at a pressure of 382 kPa. A second pulse test. Pi2, was done using the HVT. It lasted about 4 hours and recovered to about 30 percent of the Pi1 end pressure.

Testing was terminated considering that both pulse tests had consistent results indicating the zone had a relatively low permeability and did not warrant additional testing.

B3.3.2 Annulus Response

The pressure remained stable at about 322 kPa during the testing period.

B3.3.3 Bottomhole Response

The P1-line surface valve remained open during inflation, compliance and part of the Pi1 event. It was closed at Point A, (Figure B3.1) at which time the fluctuations that had been occurring stopped.

The initial P1 small pressure increase was in response to packer squeeze during inflation. The pressure at the time just before the valve was closed was about 77 kPa. The pressure appeared to be oscillating during the Psr and Pi1 events. It decreased thereafter and then started to increase near the end of the Pi2 event. The end pressure was 73 kPa.

The below atmospheric pressures may be the result of tension and water vapour pressures being formed in the line as a result of the falling liquid level in the hydraulic pathway to below the P1 transducer.

At the time of analysis, the response of the P1 pressure transducer was assumed to indicate that the fluid level in the borehole had fallen beneath the P1 transducer and also possibly below the bottom packer.

B3.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 46 kPa over the 11 hour testing period.

B3.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.4°C and 17.0°C. The surface probe temperature varied from 19.9°C to 20.0°C.

B3.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B3.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The Pi1 event responded faster in the first two minutes than during the rest of the event. Accordingly, the type curve match of the early time was not indicative of the late time data. Even the early time data, however, indicated conductivity values on the order of 3e-13 m/s, consistent with the pressure rise due to packer squeeze during Psr. The Pi2 analysis, including the expected higher effective static pressure also indicated the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B3.2. The Psr pressure increase was assigned several step-wise increasing pressures to simulate the artificial response from the packer squeeze. The Pi2 event was not included in the simulations. The more rapid falloff at the beginning of Pi1 was not well bounded. Attempts concentrated on trying to bound the general shape of the falloff.

No value of static pressure could be determined from the testing since the zone was too tight. A value of 95 kPa was used in the simulations based on the assumed trend of pressures in the borehole, including the observed P1 pressure values. With this low a conductivity, the sensitivity to changes in the static pressure would be low.

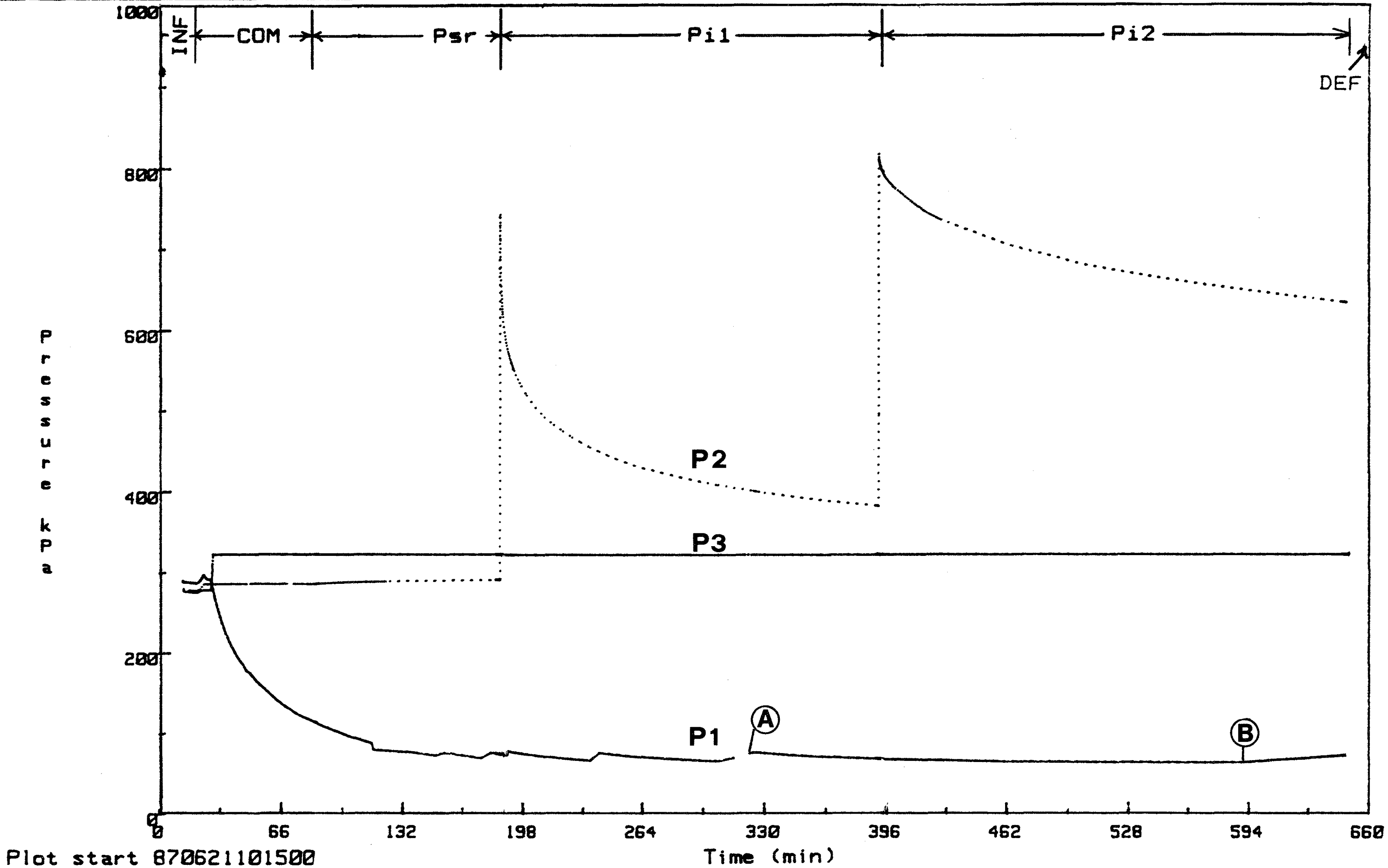
B3.4.2 Results

Borehole history pressures were between 300 and 325 kPa for most of the 7 day borehole history period. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

The pressure value at the end of the Psr event was not representative of the interval due to the packer squeeze. The value of 95 kPa used in the simulations implies that part of the zone may have been unsaturated prior to drilling. However, this was an assumption made at the time of the analyses based on the trend in the more permeable zones in the rest of the borehole. Similar responses to those obtained with 95 kPa would be seen with values to 150 kPa.

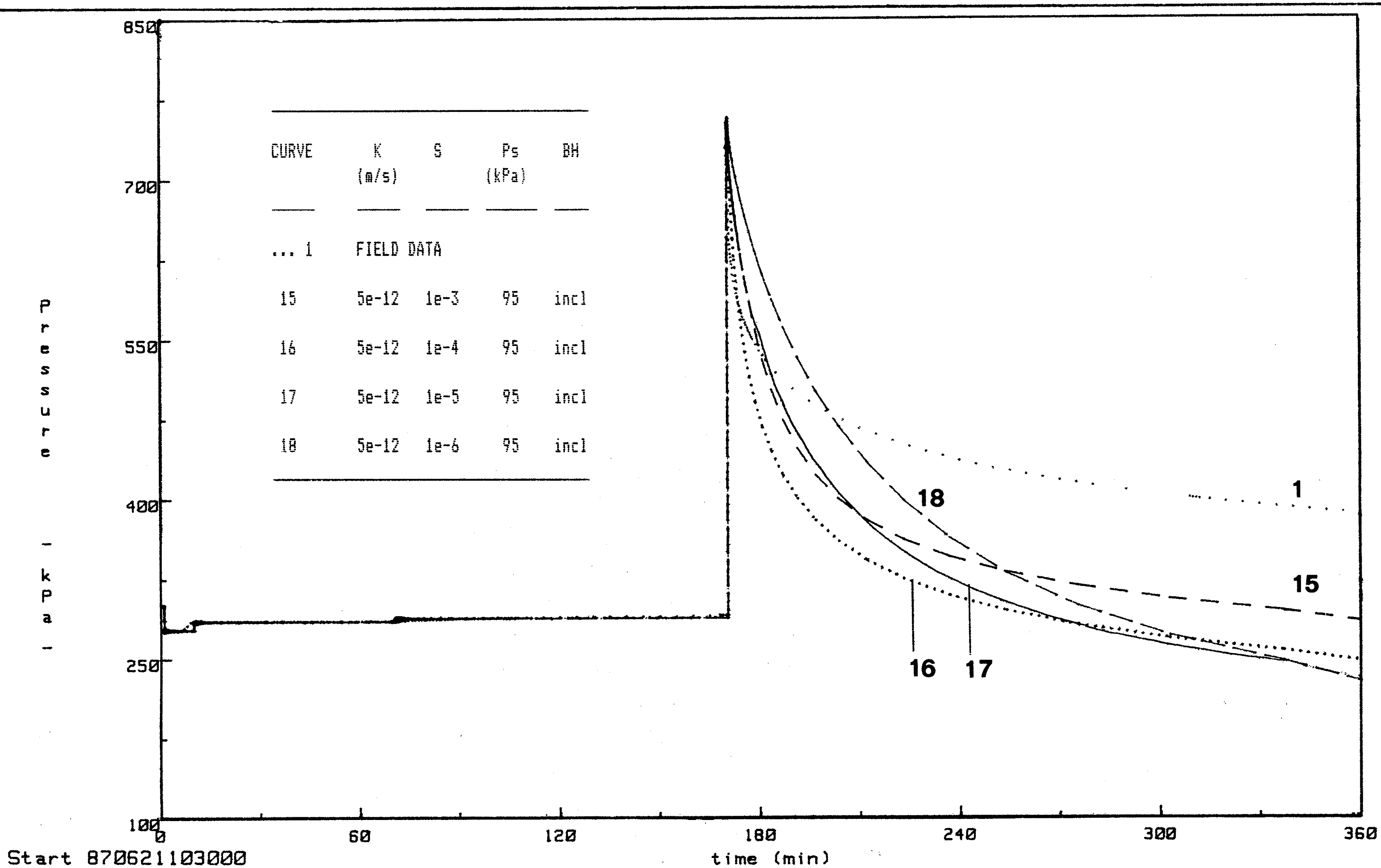
Except for the first few minutes of the pulse tests, the data were able to be bounded. The early time responses could have been analyzed in more detail, and assigned pressure steps to match the real data. Concentration then would have been to match the later response. In general, however, even including the early time data, the results of the simulations suggest hydraulic conductivity should be between 1e-12 m/s and 5e-12 m/s at storativity between 1e-6 and 1e-3. This is also consistent with the response during the Psr event.

The anomalous early time pulse test response may have been the result of a gas in the closed chamber or packer compliance, or other, different wellbore storage conditions such as a larger wellbore volume. In this instance, the initial conditions, were not as critical in affecting the response as, for example in the HGB/23.1 and 29.7 intervals involving smaller closed chamber volumes.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B3.1

PRESSURE SEQUENCE PLOT - HGB/42.5D



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B3.2

EXAMPLE SIMULATION - - HGB/42.5D

B4. APPENDIX B4: INTERVAL HGB/55.5D1

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 52.2 m and 58.8 m along the inclined borehole, respectively. This corresponded to vertical depths of 38.6 and 43.5 m, respectively. The P2 transducer was at a vertical depth of 36.7 m. Testing details are included in NIB 88-03, Section H.

B4.1 HYDROGEOLOGICAL SETTING

The interval consisted of a massive grey marlstone with fine fractures and small scale folds. RQD varied from 80 to 100 percent.

This interval was the third detailed test conducted in the HGB/62.5D interval. The previous two tests, HGB/68.7D and HGB/62.1D had not encountered the permeable zone that contributed to the screening test interval response. Packer seats were selected to cover the upper part of the HGB/62.5D screening interval.

B4.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment,
4. Screening intervals 82.5D, 62,5D and 42.5D,
5. Run-out, straddle change and run-in, and,
6. Detailed tests 76.3D, 83.3D, 68.7D, and 62.1D

Potential inflow conditions lasted for about 328 hours.

B4.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B4.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Pressure recovery 1	Pr1

7. Slug injection 1	Si1
8. Pressure recovery 2	Pr2
9. Slug withdrawal 1	Sw1
10. Pressure recovery 3	Pr3
11. Deflation	DEF

B4.3.1 Interval Response

Testing began with a 65 minute compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted 396 minutes. The pressure decreased consistently to a value of 309 kPa and was still declining.

Pi1 lasted 76 minutes. It was done using the FAV and the pressure unexpectedly dropped about 60 kPa below the Psr end pressure to 246 kPa. This response was similar to what had occurred during the HGB/62.5D screening test. A second pulse test was conducted, but this time using the HVT to attempt to first, replicate the results from Pi1, and second use a different effective radius to determine if additional data could be used to characterize the skin effect zone. Pi2 lasted 20 minutes during which time the initial overpressure of 859 kPa decayed and stabilized at a pressure of 396 kPa. The Pi2 end pressure was influenced by the tank hydraulics.

The FAV was closed after realizing the HVT influence and the Pr1 continued for 102 minutes. Pressure declined and appeared to be stabilizing at about 252 kPa. The tubing was filled to conduct the Si1 event. The initial pressure of 470 kpa declined to 425 kPa in the 130 minute event. At that time, the FAV was closed and the falloff was monitored for 135 minutes during which time the pressure decreased to 274 kPa.

Most of the water was removed from the tubing in preparation for the Sw1 event. The interval was exposed to an initial underpressure of 144 kPa. Flow lasted for 120 minutes during which time the fluid level consistently rose in the tubing. The final flowing pressure was 170 kPa. The FAV was then closed and monitoring of the final pressure buildup lasted 136 minutes. The final buildup pressure was 240 kPa.

The interval response indicated similar overall dynamics to the HGB/62.5D screening test.

B4.3.2 Annulus Response

The pressures remained stable at about 466 kPa during testing.

B4.3.3 Bottomhole Response

The surface valve remained open for most of the testing. Initially, the bottomhole pressure increased slightly to about 476 kPa, likely in response to packer squeeze. Once the surface valve had been opened, the pressure then declined consistently to an end pressure of 119 kPa. Small fluctuations that occurred may have been in response to fluid moving through the cable reel at the surface.

B4.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by 100 kPa over the 20 hour testing period.

B4.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 15.8°C and 16.8°C. The surface probe temperature varied from 19.6°C to 20.3°C.

B4.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response at least during the first part of the testing.

B4.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Data from first pulse event matched well with the type curve and indicated conductivity values on the order of 3e-10 m/s. No Pi2 event analysis was considered. Data from both slug events matched well with the type curve and indicated conductivity values on the order of 3e-9 m/s. Straight-line horner-type analyses of the recovery periods following the slug events also yielded conductivities on the order of 2e-9 to 6e-9 m/s.

The GLIMPSE model was used to attempt to bound the interval data. The response clearly suggested that a skin effect had been overcome during the Pi1 event. Pi1 responded more slowly than the slug flow and recovery events. The simulations were then segregated into three periods; the first to the end of Psr, the second the Pi1 and Pi2 events and the third, the three Qcr and Pr events. Simulation runs demonstrating the approach for the slug flow and recovery events are shown in Figure B4.2.

A relatively well documented static pressure could be extrapolated from the end pressures of events following Psr. These indicated a consistent value of 245 kPa. Borehole history was likely limited by the development of a skin effect, broken through during the Pi1 event. Therefore, there would not be any borehole history pressure influence on the events following Psr.

Borehole history was included and then dropped from the bounding attempts for both the Pi1 event and the final events. Attempts to bound the data when it was included resulted in having to use static pressures on the order of 150 kPa.

The assumption that a tighter skin zone was formed prior to testing made it logical to exclude the borehole history pressures.

B4.4.2 Results

This zone responded is believed to be the one that contributed to the response of the HGB/62.5D screening test.

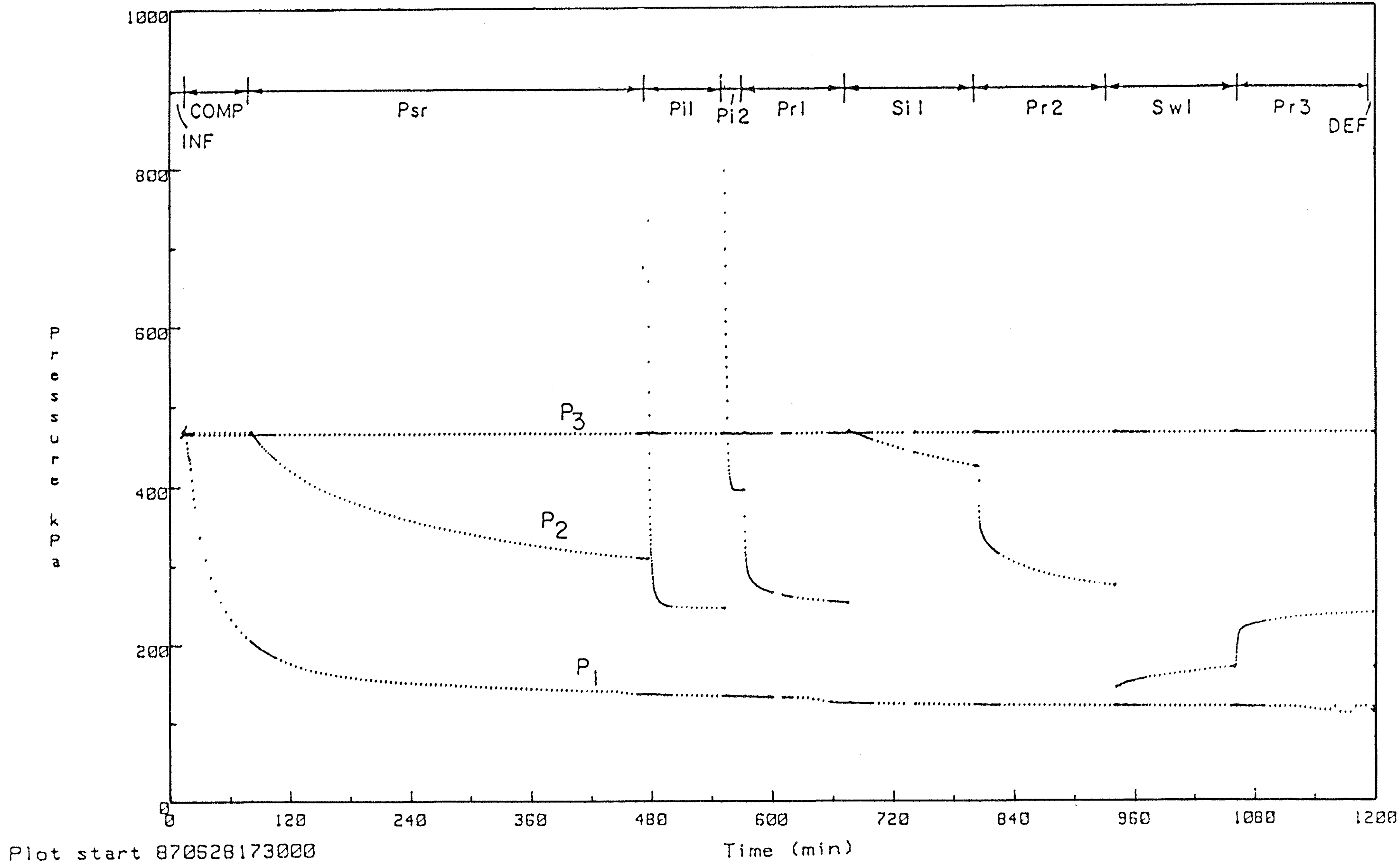
Borehole history pressures were above 450 kPa for most of the 14 day borehole history period. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during the first part of the testing. However, once the skin zone was penetrated, the response was not likely influenced by these earlier higher overpressures.

The pressure value at the end of the shut-in events indicated consistent end pressures of about 240 to 250 kPa. Results of the bounding analysis excluding borehole history indicated this was a reasonable range. This value corresponds to a hydraulic head elevations of about 471 m (asl), compared to the drilling gallery floor and Lake Uri elevations of 494 and 433 kPa.
When borehole history was included, the value required to bound the data, using similar conductivity values, was about 150 kPa. This value corresponds to a hydraulic head elevations of about 461 m (asl).

The COM and Psr events were able to be bounded with a hydraulic conductivity value of about 3e-10 m/s over a reasonable range of storativity.. The pulse event data were able to be bounded with hydraulic conductivity values between 3e-10 and 3e-9 m/s with a storativity of 1e-6 and a static pressure of 150 kPa when borehole history was included.

The slug flow and recovery event data were able to be bounded with hydraulic conductivity values between 1e-9 and 1e-8 m/s with storativity ranging from 1e-4 to 1e-3 at a static pressure of 150 kPa with borehole history included. When borehole history was excluded, bounding was done with a lower hydraulic conductivity range between 1e-9 and 5e-9 m/s with a storativity from 1e-4 to 1e-3 at a static pressure of 245 kPa.

More detailed analysis would be required to determine whether the removal of the borehole history period pressures was justified, even under the assumption of a skin effect. Changing skin effect and variations in the duration of the time that the skin blocked transmission of the overpressures into the interval are examples of the potential conditions that would have influenced the interval response.



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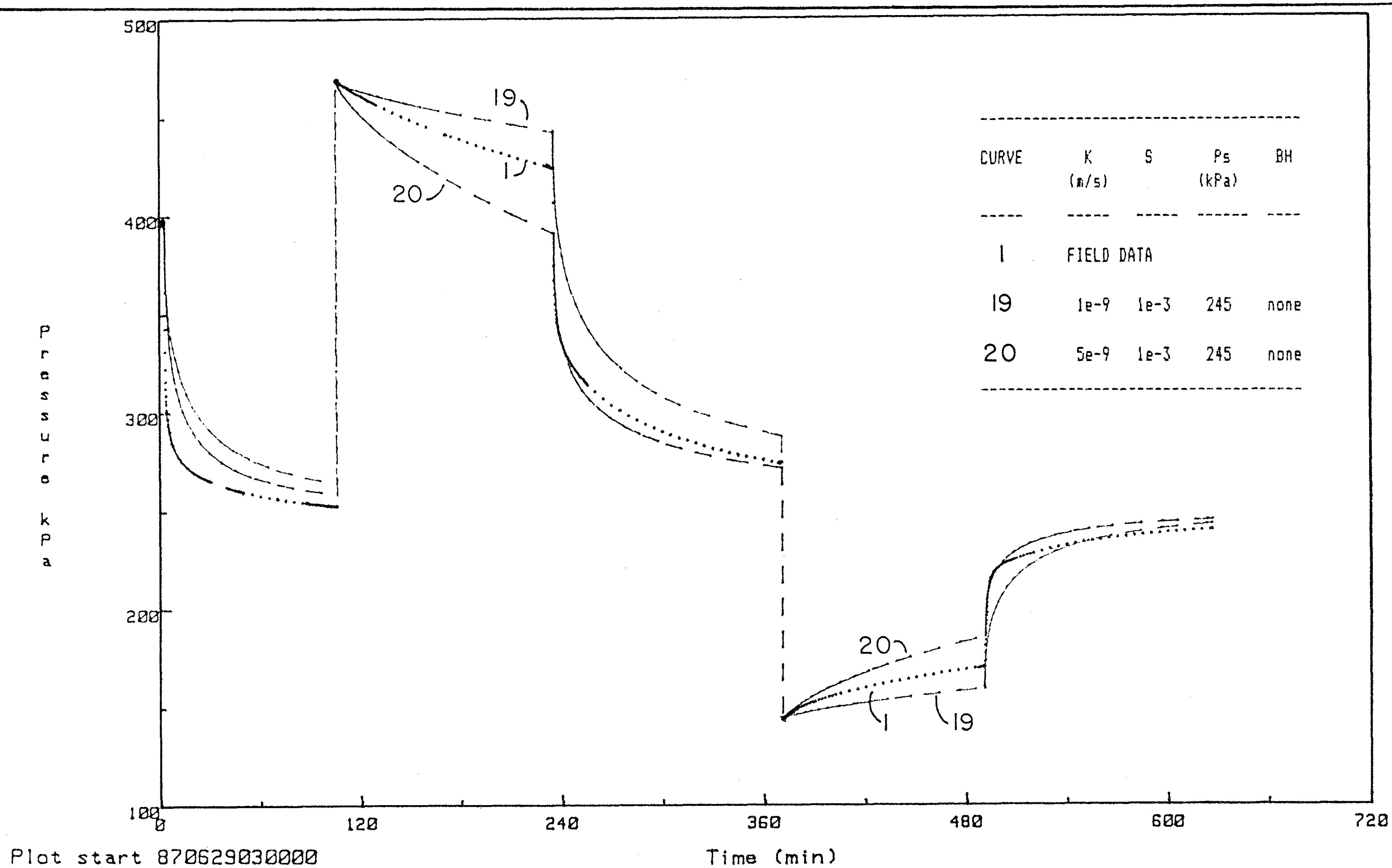
PRESSURE SEQUENCE PLOT - HGB/55.5D1



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B4.2

EXAMPLE SIMULATION - - HGB/55.5D1

B5. APPENDIX B5: INTERVAL HGB/55.5D2

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 52.2 m and 58.8 m along the inclined borehole, respectively. This corresponded to vertical depths of 38.6 and 43.5 m, respectively. The P2 transducer was at a vertical depth of 36.7 m. Testing details are included in NIB 88-03, Section K.

B5.1 HYDROGEOLOGICAL SETTING

Previous testing in this interval had been done. The purpose of this testing was to attempt to evaluate if the response had changes with time, and to set up the interval for the gas test that was to follow.

The interval consisted of a massive grey marlstone with fine fractures and small scale folds. RQD varied from 80 to 100 percent.

This was the fourth detailed test conducted in the HGB/62.5D interval. The previous test, HGB/55.5D1 had encountered the permeable zone that contributed to the screening test interval response. Packer seats were selected to cover the same zone as the previous detailed test.

B5.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment,
4. Screening intervals 82.5D, 62,5D and 42.5D,
5. Run-out, straddle change and run-in,
6. Detailed tests 76.3D, 83.3D, 68.7D, 62.1D, 55.5D1, 29.7D and 23.1D, and
7. Run-out, modify tool and run-in.

Potential inflow conditions lasted for about 388 hours.

B5.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B5.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery 1	Psr1
4. Shut-in static recovery 2	Psr2
5. Pulse injection 1	Pi1
6. Slug withdrawal 1	Sw1
7. Pressure recovery 1	Pr1
8. Preparation for the HGB/55.5D gas test	

The P1 line porting was modified prior to testing this interval in preparation for the gas test that was to follow. As a result, the P1 line to surface was now hydraulically connected to the interval.

B5.3.1 Interval Response

Testing began with a 31 minute compliance period during which time there was no change in the fluid level in the tubing. Psr1 lasted 700 minutes. The general trend of the response was similar to what had been observed during the HGB/55.5D1 test. However, the irregularity and oscillations in the data were not typical of a shut-in response. The final Psr1 pressure was 380 kPa (Figure B5.1, Point A), about 140 kPa higher than the expected pressure based on the previous detailed testing data. It was suspected that the fact that the P1 line had been closed during this time caused this higher pressure, rather than, for example, the previous borehole history opposite the zone.

A second Psr event, Psr2, was conducted with the P1 line valve open. It lasted 521 minutes. Once the valve was opened, the pressure increased to 380 kPa. It oscillated and generally decreased over the event to a final pressure of about 450 kPa. This value likely reflected the height of the column of water in the line to surface.

Testing proceeded with a Pi1 event that lasted 207 minutes. It was done by applying pressure to the interval with the FAV closed. The following pressure response was similar to what had previously occurred during both the HGB/55.5D1 and 62.5D Pi1 events. The initial pressure of 666 kPA fell to 231 kPa. Ten minutes into the event, the P1 valve had been opened at the surface. No change occurred in the response. It was likely that the overpressure through the line blew down the fluid in the tubing to a level below the cable reel. The response was then in response to a open line to surface condition.

Most of the water was removed from the tubing in preparation for the Sw1 event. The interval was exposed to an initial underpressure of 201 kPa. Flow lasted for 315 minutes during which time the fluid level consistently rose in the tubing. The final flowing pressure was 216 kPa. The FAV was then closed to begin monitoring of the final pressure buildup. The monitoring was terminated after 30 minutes because of the lack of pressure response. The P1 line to surface, now connected to the interval created slug type conditions. Preparations then began for the gas test.

The interval response indicated similar overall dynamics to the HGB/62.5D screening test. Since the P1 transducer port was connected to the P1 line, the both the P1 and P2 transducers measured the interval pressure response. Differences in the measured pressure occurred as a result of the different tubing porting inside the testing tool.

B5.3.2 Annulus Response

The pressures remained stable at about 465 kPa during testing.

B5.3.3 Bottomhole Response

The bottomhole response could not be monitored given the configuration of the tool required for the gas test.

B5.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 70 kPa over the 30 hour testing period.

B5.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 15.7°C and 16.8°C. The surface probe temperature varied from 20.0°C to 20.8°C.

B5.4 INTERPRETATION AND RESULTS

B5.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

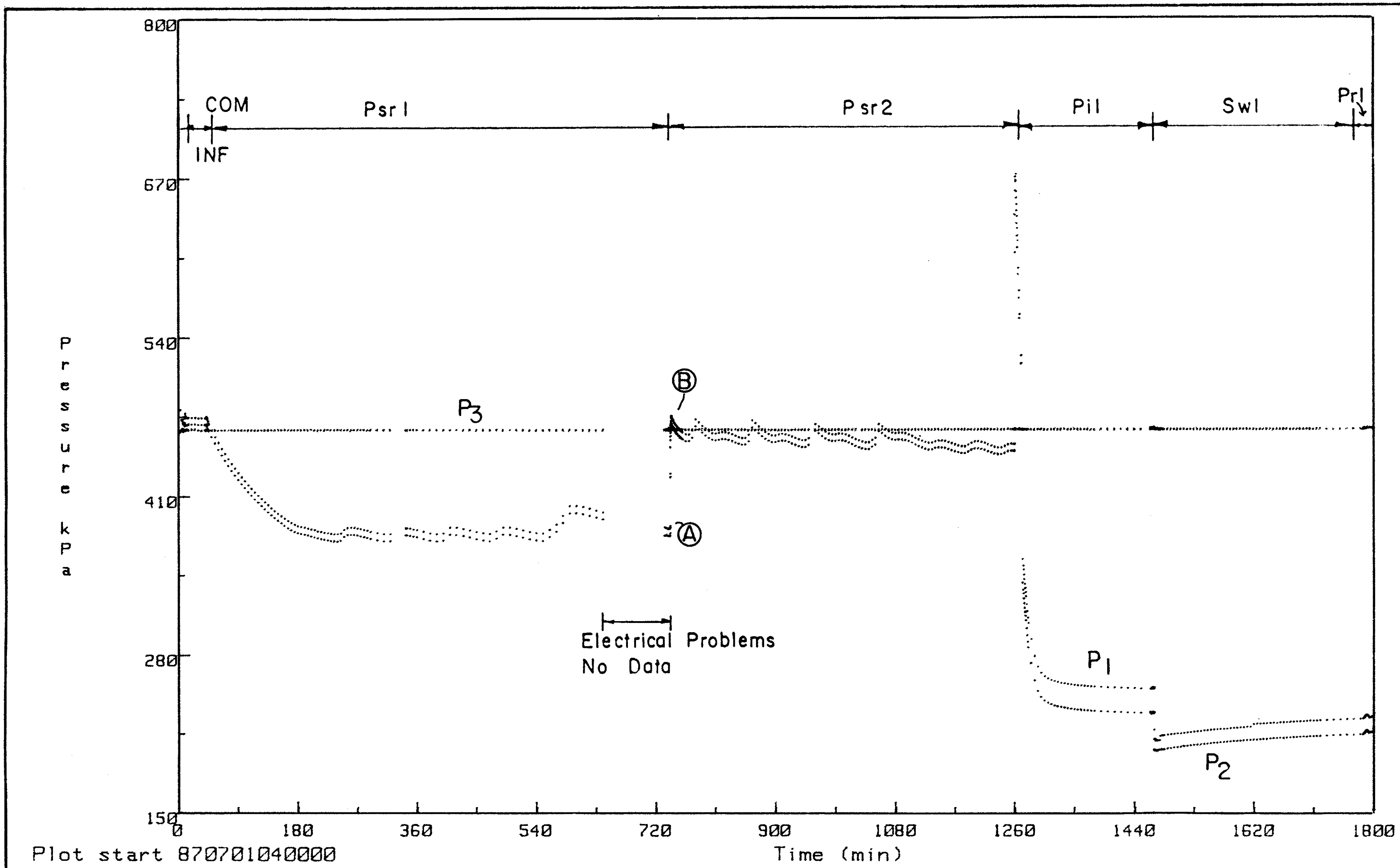
Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Data from first pulse event matched well with the type curve and indicated conductivity values on the order of 5e-9 m/s.

No other analyses were conducted because of the inability to incorporate the influences of the hydraulic line to surface.

B5.4.2 Results

This zone responded in a similar manner to the previous detailed test. The hydraulic parameter values are expected to be similar.

The tool modifications precluded conducting testing that could replicate the HGB/55.5D1 events. Therefore, it was not possible to evaluate with certainty, if the interval conditions had changed between the two testing activities. The results of the Pi1 event showed consistent trends.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B5.1

PRESSURE SEQUENCE PLOT - HGB/55.5D2

B6. APPENDIX B6: INTERVAL HGB/55.5D GAS TEST

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 52.2 m and 58.8 m along the inclined borehole, respectively. This corresponded to vertical depths of 38.6 and 43.5 m, respectively. The P2 transducer was at a vertical depth of 36.7 m. Testing details are included in NIB 88-03, Section L.

B6.1 HYDROGEOLOGICAL SETTING

Previous testing in this interval had been done. The purpose of this testing was to attempt to evaluate the response of the interval to injections of gas a different constant (mass) rates.

The interval consisted of a massive grey marlstone with fine fractures and small scale folds. RQD varied from 80 to 100 percent.

This was the fifth detailed test conducted in the HGB/62.5D interval. Results of the previous two detailed tests in this interval, HGB/55.5D1 and HGB/55.5D2, indicated this was the permeable zone that contributed to the screening test interval response. Packer seats were not changed from the HGB/55.5D2 detailed test since there was no deflation.

B6.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment,
4. Screening intervals 82.5D, 62,5D and 42.5D,
5. Run-out, straddle change and run-in,
6. Detailed tests 76.3D, 83.3D, 68.7D, 62.1D, 55.5D1, 29.7D and 23.1D,
7. Run-out, modify tool and run-in, and,
8. Detailed test 55.5D2 and preparations for testing.

Potential inflow conditions lasted for about 418 hours.

B6.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B6.1, included:

1. Constant rate injection 1		Qcr1
2. Pressure recovery	1	Pr1
3. Constant rate injection 2		Qcr2
4. Pressure recovery 2		Pr2
5. Constant rate injection 3		Qcr3
6. Constant rate injection 4		Qcr4
7. Pressure recovery 3		Pr3
8. Deflation		DEF

The P1 line porting was modified prior to testing. As a result, the formerly referred to 'P1 line-to-surface' was now hydraulically connected to the interval.

Modifications were made to the tool to allow gas to be injected either through the tubing string with the FAV open, or through the smaller diameter hydraulic line with the FAV closed.

Tanks of compressed nitrogen gas were connected together at the surface to provide a reservoir for the injection testing. These tanks were then connected through the flow manifold board to the wellhead. Flow rates and line pressures could be monitored in this manner.

B6.3.1 Interval Response

Testing began after fluid had been removed from the interval by swapping and overpressuring the system with gas at the surface.

The first Qcr1 lasted 318 minutes during which time gas was injected at an average rate of 11.5 gm/min. The pressure increased from 222 kPa to a final injection flow pressure of 735 kPa. The Pr1 event was monitored for 157 minutes during which time the pressure decayed to 321 kPa.

Qcr2 lasted 334 minutes during which time gas was injected at an average rate of 13.5 gm/min. The pressure increased from 321 kPa to a final injection flow pressure of 823 kPa. The Pr2 event was monitored for 113 minutes during which time the pressure decayed to 319 kPa.

Qcr2 lasted 208 minutes during which time gas was injected at the same average rate of 13.5 gm/min.

The pressure increased from 319 kPa to a final injection flow pressure of 818 kPa. The injection rate was then increased to 27 gm/min for Qcr4. The pressure increased from 818 kPa to a final injection flow pressure of 1072 kPa during the 165 minute event. The final Pr3 event was monitored for 88 minutes during which time the pressure decayed to 394 kPa.

B6.3.2 Annulus Response

The pressures remained stable at about 464 kPa during testing.

B6.3.3 Bottomhole Response

The bottomhole response could not be monitored given the configuration of the tool required for the gas test.

B6.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 40 kPa over the 23 hour testing period.

B6.3.5 Temperature Response

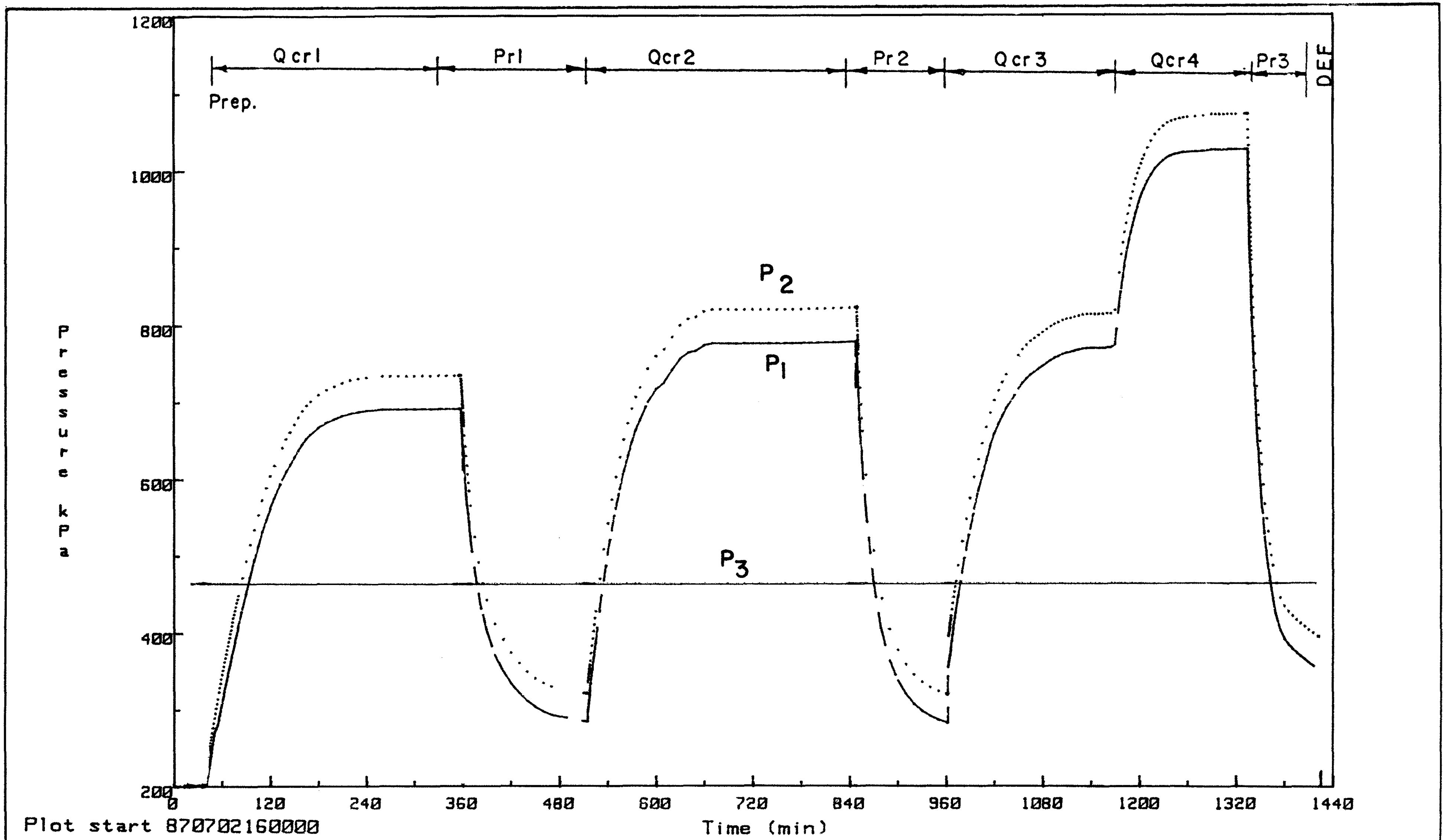
Temperatures at sensor depth remained relatively stable between 15.7°C and 16.8°C. The surface probe temperature varied from 20.0°C to 20.8°C.

B6.4 INTERPRETATION AND RESULTS

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. However, no borehole history was included in the analysis of any of the data.

Preliminary results of testing were provided in a QLR report shortly after the end of testing. All onsite analyses were done using the 'P-squared' approach typically used for hydraulic characterization of gas testingtransient responses.

The report following Figure B6.1 was prepared in response to NAGRA's request to have a detailed analysis done of the gas testing. It is included in it's entirety. It illustrates a typical detailed analysis that could be expected for any of the intervals. In this instance, the conditions for the gas testing suggested that borehole history not be included.



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B6.1

PRESSURE SEQUENCE PLOT - HGB/55.5D-GAS

B7. APPENDIX B7: INTERVAL HGB/62.1D

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 58.8 m and 65.4 m along the inclined borehole, respectively. This corresponded to vertical depths of 43.5 and 48.4 m, respectively. The P2 transducer was at a true vertical depth of 41.6 m. Testing details are included in NIB 88-03, Section G.

B7.1 HYDROGEOLOGICAL SETTING

The interval consisted of a grey, massive marlstone with fine fractures and small scale folds and layering offsets. RQD varied from 50 to 90 percent.

This interval was the second of three detailed tests conducted in the HGB/62.5D screening interval. Packer seats were selected to cover the middle part of the screening test interval.

B7.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 82.5D, 62.5D, and 42.5D,
5. Changing of straddle, run-in of equipment, and,
6. Detailed tests 76.3D, 83.3D, and 68.7D.

Potential inflow conditions lasted for about 305 hours.

B7.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B7.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Pressure recovery 1	Pr1
7. Deflation	DEF

B7.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted about 6 hours. The pressure decreased in a consistent manner to a final value of 350 kPa.

Pi1 was done using the FAV and recovered by about 95 percent in 145 minutes and was terminated at a pressure of 378 kPa. A second pulse test. Pi2, was done using the HVT with a similar initial overpressure of 1014 kPa. It lasted about 5 hours and recovered to about 30 percent of the Pi1 end pressure.

The downhole FAV was then closed to monitor the final pressure recovery, Pr1. This monitoring lasted 147 minutes during which time the pressure decreased by 296 kPa to a final value of 527 kPa.

Testing was terminated considering that all events had consistent results indicating the zone had a relatively low permeability and did not warrant additional testing.

B7.3.2 Annulus Response

The pressure remained stable at about 514 kPa during the testing period. However, periodic additions to the annulus to maintain the level full were made during that time. The total volume added was about 1 litre.

B7.3.3 Bottomhole Response

The P1-line surface valve was closed at the beginning of inflation and the pressure increased by about 7 kPa. The valve was opened four minutes into inflation and the pressure began to decrease. It decreased in a consistent manner over the duration of testing to a final value of 163 kPa.

B7.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 40 kPa over the 17 hour testing period.

B7.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.0°C and 16.9°C. The surface probe temperature varied from 19.4°C to 20.2°C.

B7.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B7.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Both the pulse tests had responses that indicated conductivity values on the order of 5e-12 to 1e-11 m/s. Results indicated the zone had relatively low conductivity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B7.2. The Pi2 pressure falloff was assigned several step-wise decreasing pressures to account for the tank hydraulics and allow the final Pr1 event to be included in the analysis.

No value of static pressure could be determined from the testing for this interval since the zone was too tight. However, values of 220 kPa and 245 kPa had been relatively well documented for the HGB/62.5D and 55.5D1 intervals, respectively. Accordingly, an initial value of 275 kPa was used for this interval. Sensitivity analyses using static pressures as low as 175 kPa were included. With the range of conductivity seen for the interval, the sensitivity to changes on the order of 100 kPa should be start to become more pronounced.

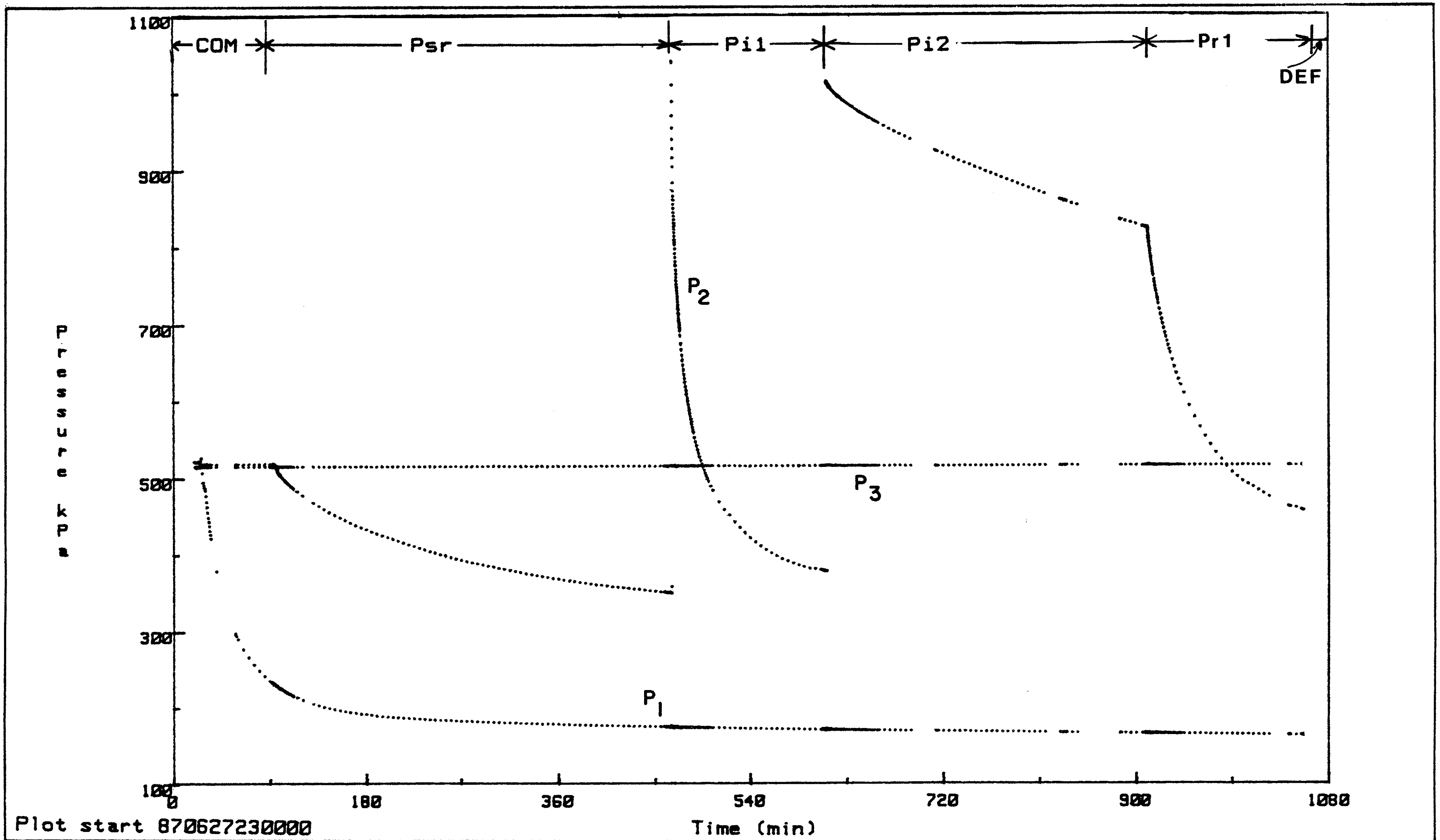
B7.4.2 Results

Borehole history pressures were between 500 and 525 kPa during most of the borehole history period which had lasted about 13 days. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability for the interval meant that that a value of static pressure considered representative of interval conditions needed to be estimated initially from other data.

The pressure value of 275 used was consistent with testing values in adjacent intervals. It appeared to be reasonable given the pressure at the end of the Psr event was 350 kPa and still decreasing and the similar trend from the Pi1 event. Results of the bounding indicated it provided a reasonable result.

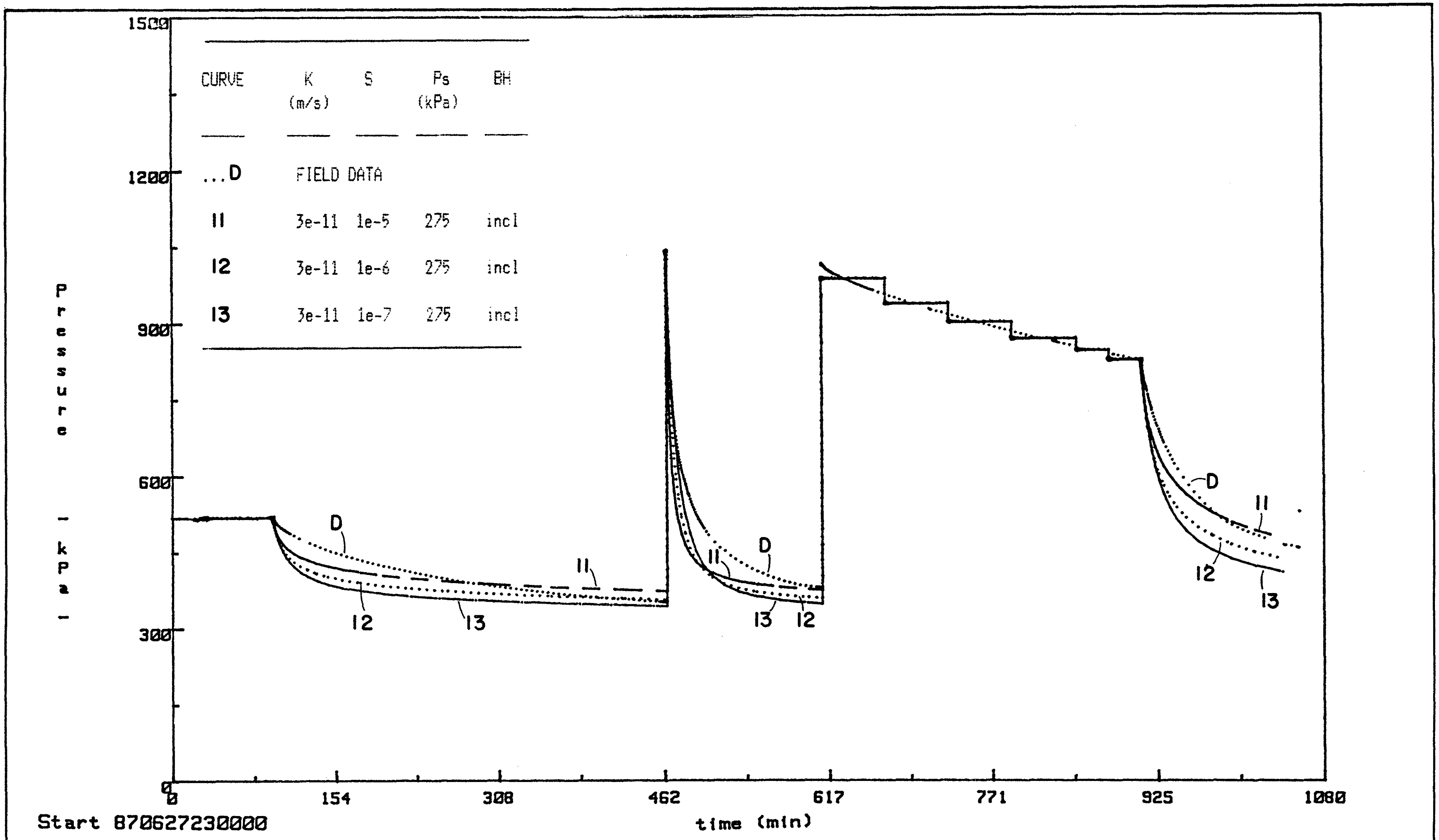
The data were bounded using hydraulic conductivity values between 1e-11 m/s and 5e-11 m/s at storativity values between 1e-6 and 1e-3.

The hydraulic head value corresponding to a pressure of 275 kPa is 470 m (asl), compared to the drilling gallery floor and Lake Uri levels of 494 and 433 m (asl), respectively.



NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B7.1

PRESSURE SEQUENCE PLOT - HGB/62.1D



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EXAMPLE SIMULATION - HGB/62.1D

B8. APPENDIX B8: INTERVAL HGB/62.5D

This interval was tested using a double straddle packer assembly with a length of 19.0 m. The upper and lower packer seats were at lengths of 53.0 m and 72.0 m along the inclined borehole, respectively. This corresponded to vertical depths of 39.1 and 53.5 m, respectively. The P2 transducer was at a vertical depth of 37.3 m. Testing details are included in NIB 88-03, Section B.

B8.1 HYDROGEOLOGICAL SETTING

The interval consisted of a massive grey marlstone with open fractures and vugs some of which were mineralized. RQD varied from 50 to 100 percent.

This interval was the second test conducted and the second of three screening intervals tested in HGB. Packer seats were selected to interval above the HGB/82.5D screening interval.

B8.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment, and
4. Screening test interval 82.5D.

Potential inflow conditions lasted for about 131 hours.

B8.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B8.1, included:

1.	Inflation	INF
2.	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
5.	Pulse injection 2	Pi2
6.	Constant rate injection 1	Qcr1
7.	Pressure recovery 1	Pr1
8.	Constant rate injection 2	Qcr2

9. Pressure recovery 2 — Pr2
10. Constant rate injection 3 — Qcr3
11. Pressure recovery 3 — Pr3
12. Deflation — DEF

B8.3.1 Interval Response

Testing began with a 53 minute compliance period during which time there was no change in the fluid level in the tubing. The Psr lasted 380 minutes. The pressure decreased consistently to a value of 318 kPa and was still declining.

Pi1 lasted 110 minutes. It was done using the FAV and the pressure unexpectedly dropped 100 kPa below the Psr end pressure to 220 kPa. A second pulse test was conducted to attempt to replicate the results from Pi1. Pi2 lasted 69 minutes during which time the initial overpressure of 925 kPa decayed and stabilized at a pressure of 220 kPa.

Injection equipment was set up and a series of three flow and recovery=very periods were conducted. Qcr1 lasted 56 minutes with an average rate of 75 ml/min. The interval pressure stabilized and remained relatively constant at about 440 to 445 kPa. The Pr2 recovery was monitored for 33 minutes during which time the pressure decayed to 220 kPa.

Qcr2 lasted 107 minutes with an average rate of 105 ml/min. The interval increased to a final flowing pressure of 674 kPa. The Pr2 recovery was monitored for 62 minutes during which time the pressure decayed to 225 kPa.

Qcr1 lasted 221 minutes with an average rate of 324 ml/min. The interval increased to a final flowing pressure of 1160 kPa. The Pr2 recovery was monitored for 173 minutes during which time the pressure decayed to 338 kPa.

Periodic adjustments were made to limit and maintain an average pumping rates during the injection tests. Each falloff period achieved the desired 80 percent recovery.

B8.3.2 Annulus Response

The pressures remained stable at about 467 kPa during testing.

B8.3.3 Bottomhole Response

The surface valve remained open for most of the testing. Initially, the bottomhole pressure increased slightly to about 450 kPa, likely in response to packer squeeze. Once the surface valve had been opened, the pressure then declined consistently to an end pressure of 127 kPa.

B8.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It fluctuated by up to about 10 kPa over the 21 hour testing period.

B8.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.5°C and 17.2°C. The surface probe temperature varied from 19.5°C to 19.9°C.

B8.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response at least during the first part of the testing.

B8.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. Data from both pulse tests matched well with the type curves and indicated conductivity values on the order of 2e-10 m/s. Straight-line horner-type analyses of the Pr1, Pr2 and Pr3 recovery periods following the constant rate injection tests yielded conductivities on the order of 2e-9 m/s.

The GLIMPSE model was used to attempt to bound the interval data. The response clearly suggested that a skin effect had been overcome during the Pi1 event. Pulse tests responded even more slowly than the injection and recovery periods. The simulations were then segregated into three periods; the first to the end of Psr, the second the Pi1 and Pi2 events and the third, the three Qcr and Pr events. Simulation runs demonstrating the approach for the second and third periods are shown in Figures B8.2 and B8.3.

The flow rate periods were assigned one or more constant pressure steps to simulate the injection period data. The analysis of the last six events concentrated on bounding the recovery period data.

A relatively well documented static pressure could be extrapolated from the end pressures of events following Psr. These indicated a consistent value of 220 kPa. Borehole history was likely limited by the development of a skin effect, broken through during the Pi1 event. Therefore, there would not be any borehole history pressure influence on the events following Psr.

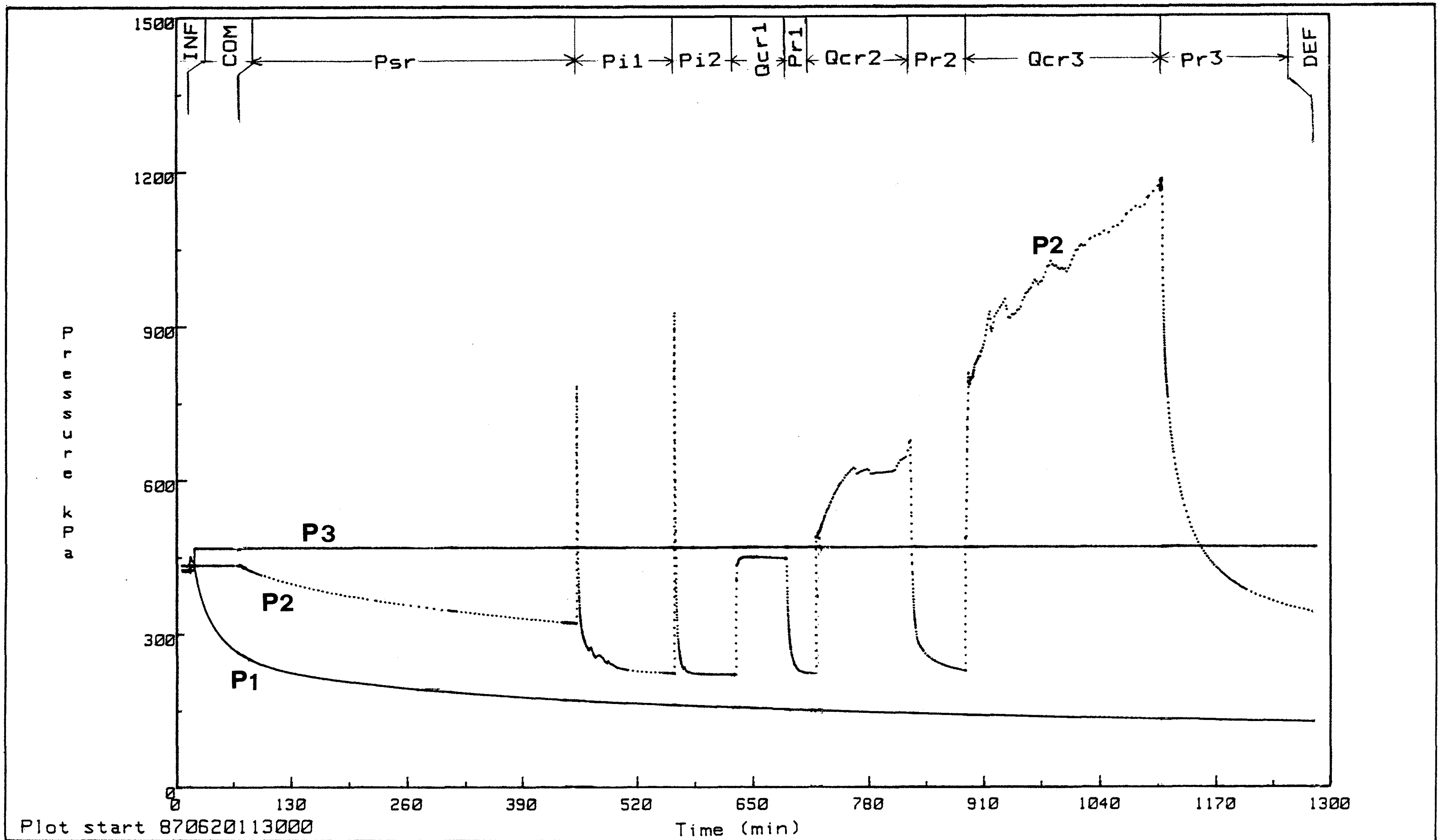
B8.4.2 Results

Borehole history pressures were between 300 and 475 kPa for most of the 5.5 day borehole history period. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during the first part of the testing. However, once the skin zone was penetrated, the response may not have been influenced by these earlier higher overpressures.

The pressure value at the end of the shut-in events indicated consistent end pressures of 220 kPa. Results of the bounding analysis indicate this is a reasonable value. This value corresponds to a hydraulic head elevations of 468 m (asl), compared to the drilling gallery floor and Lake Uri elevations of 494 and 433 kPa.

The pulse event data were able to be bounded with hydraulic conductivity values between 1e-10 and 5e-10 m/s over a reasonable range of storativity. The recovery event data were able to be bounded with hydraulic conductivity values between 1e-9 and 1e-8 m/s over a range of storativity from 1e-5 to 1e-3.

The anomalous responses of the COM and Psr events were affected by a skin condition that indicated a hydraulic conductivity at least one order of magnitude lower than the pulse test responses. Enen the difference in conductivity exhibited between the pulse and recovery events could reflect a changing skin condition. No indication of the time at which the skin developed, or it's estimated thickness can be made from the data.



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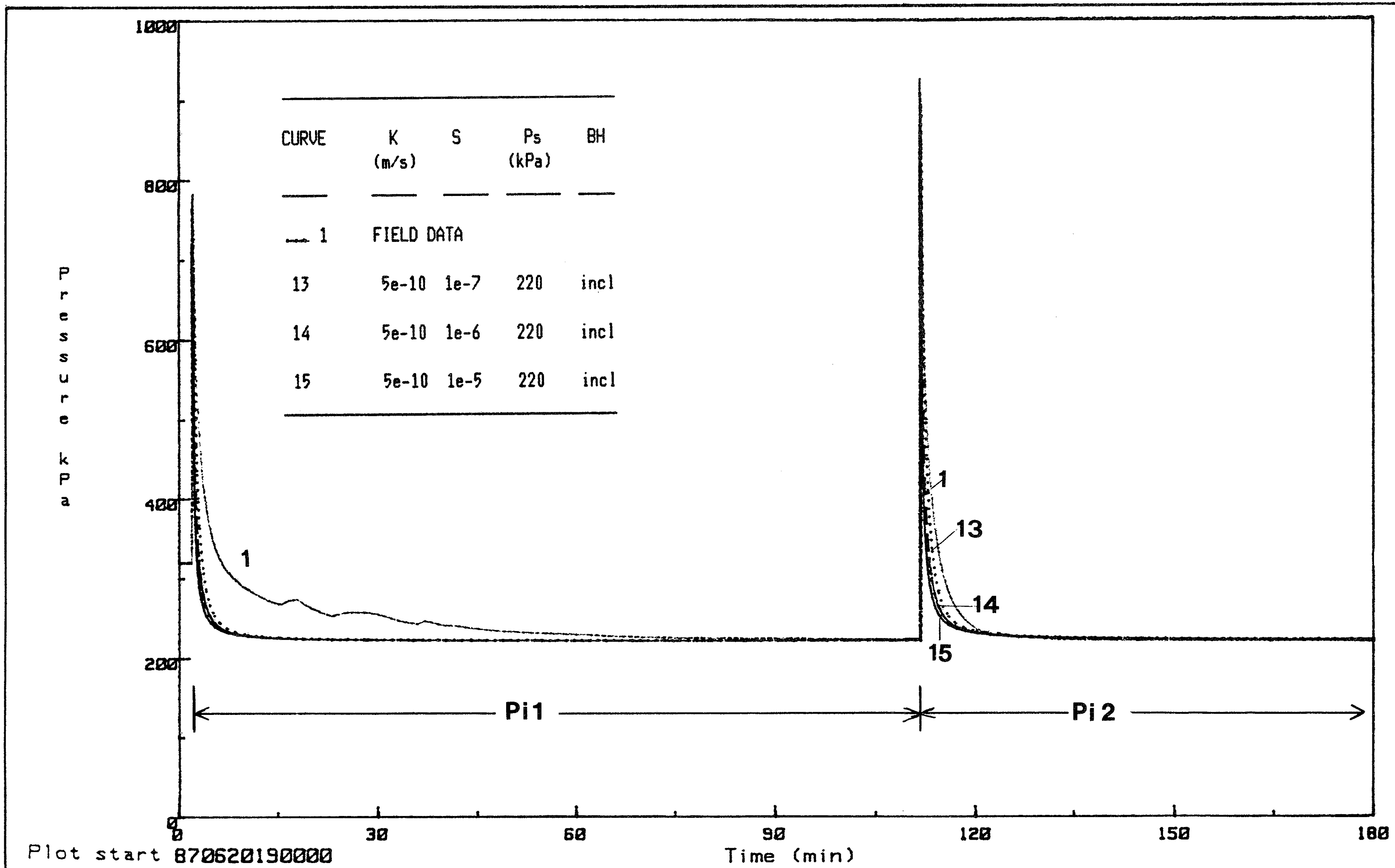
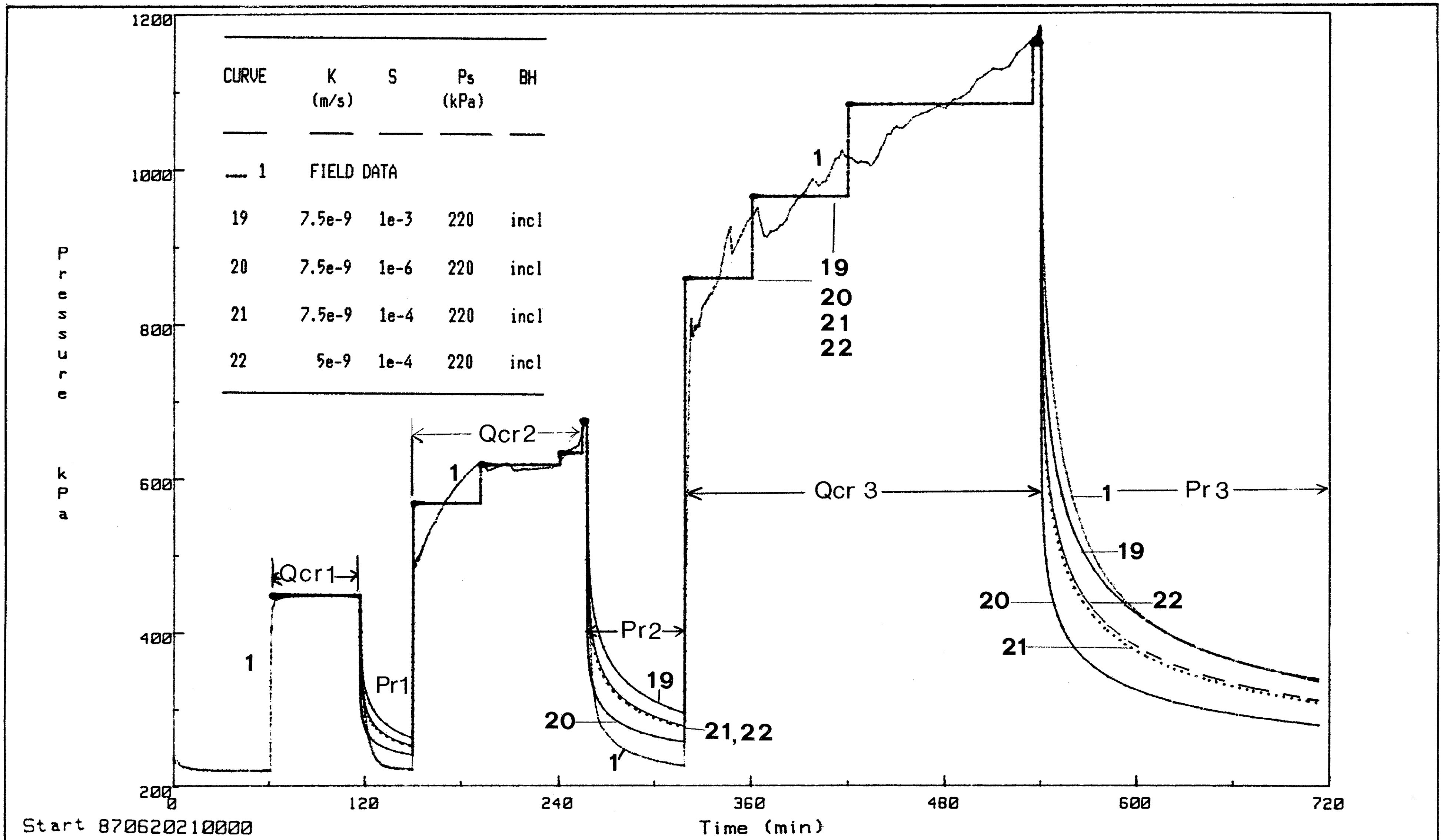
PRESSURE SEQUENCE PLOT - HGB/62.5D



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B8.2

EXAMPLE SIMULATION 1 - HGB/62.5D



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B8.3

EXAMPLE SIMULATION 2 - HGB/62.5D

B9. APPENDIX B9: INTERVAL HGB/68.7D

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 65.4 m and 72.0 m along the inclined borehole, respectively. This corresponded to vertical depths of 48.4 and 53.4 m, respectively. The P2 transducer was at a vertical depth of 46.6 m. Testing details are included in NIB 88-03, Section F.

B9.1 HYDROGEOLOGICAL SETTING

The interval consisted of a grey, massive marlstone with fine fractures and small scale folds and layering offsets. The rock became clayey marlstone below 72 m. Fractures were rarely mineralized. RQD varied from 50 to 90 percent.

This interval was the first of three detailed tests conducted in the HGB/62.5D screening interval. Packer seats were selected to cover the lowest part of the screening test interval.

B9.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 82.5D, 62.5D, and 42.5D,
5. Changing of straddle, run-in of equipment, and,
6. Detailed tests 76.3D, and 83.3D.

Potential inflow conditions lasted for about 278 hours.

B9.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B9.1, included:

1.	Inflation	INF
2.	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
5.	Pulse injection 2	Pi2
6.	Pulse injection 3	Pi3
7.	Pressure recovery 1	Pr1

8.	Slug withdrawal 1	Sw1
9.	Pressure recovery 2	Pr2
10.	Deflation	DEF

B9.3.1 Interval Response

Testing began with a 1 hour compliance period during which time there was a 0.3 kPa decrease in pressure. The Psr lasted about 6 hours. The pressure decreased in a consistent manner to a final value of 424 kPa.

Pi1 was done using the FAV and recovered by about 90 percent in 98 minutes and was terminated at a pressure of 441 kPa. A second pulse test, Pi2, was done again using the FAV but with a higher initial overpressure of 1384 kPa. This test lasted 31 minutes and recovered to about 454 kPa. A third pulse test, Pi2, was done using the HVT with a similar initial overpressure of 1216 kPa. It lasted 51 minutes and recovered to about 70 percent of the Pi2 end pressure.

The downhole FAV was then closed to monitor the pressure recovery, Pr1. This monitoring lasted 146 minutes during which time the pressure decreased by 159 kPa to a final value of 516 kPa and was still decreasing.

Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 156 kPa at the start of Sw1. An underpressure was used to see if fluid would flow up into the tubing. An increase of 20 kPa was recorded during 182 minutes at which time the FAV was closed and the final pressure buildup was monitored.

The final recovery, Pr2, was monitored for 288 minutes. The pressure increased by only 36 kPa and was increasing slowly at the end of testing in the interval.

B9.3.2 Annulus Response

The pressure remained stable at about 563 kPa during the testing period. However, periodic additions to the annulus to maintain the level full were made during that time. The total volume added was less than 1 litre.

B9.3.3 Bottomhole Response

The P1-line surface valve was closed at the beginning of inflation and the pressure increased by about 10 kPa. The valve was opened four minutes into inflation and the pressure began to decrease. It decreased in a consistent manner over the duration of testing to a final value of 198 kPa.

B9.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 80 kPa over the 21 hour testing period.

B9.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.3^{o}C and 17.0^{o}C. The surface probe temperature remained stable at 20.2^{o}C.

B9.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B9.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The first two pulse tests had responses that indicated conductivity values on the order of 1e-12 m/s. However, tha amount of flow that occurred during Sw1 indicated a higher value of about 1e-12 m/s. The results of the pulse and slug events were not consistent.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B9.2. The Pi3 pressure falloff should have been assigned decreasing pressures to account for the tank hydraulics. However, it was of such a short duration and the recovery so small that it was treated just as a larger shut-in volume.

No value of static pressure could be determined from the testing for this interval since the zone response was not consistent. However, a value of 220 kPa had been relatively well documented for the HGB/62.5D interval. Accordingly, an initial value of 250 kPa was used for this interval.

B9.4.2 Results

Borehole history pressures were between 550 and 575 kPa during most of the borehole history period which had lasted about 12 days. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the inconsistent interval response and lack of bounding meant that that a value of static pressure considered representative of interval conditions would have to be estimated from other borehole data.

The pressure value of 250 kPa used was consistent with testing values in the HGB/62.5D screening interval. Because of the inconsistent response during testing, however, it is difficult to assess whether this value provided confirming results. Based on the results from other intervals, a reasonable static pressure value would be between 250 and 300 kPa.

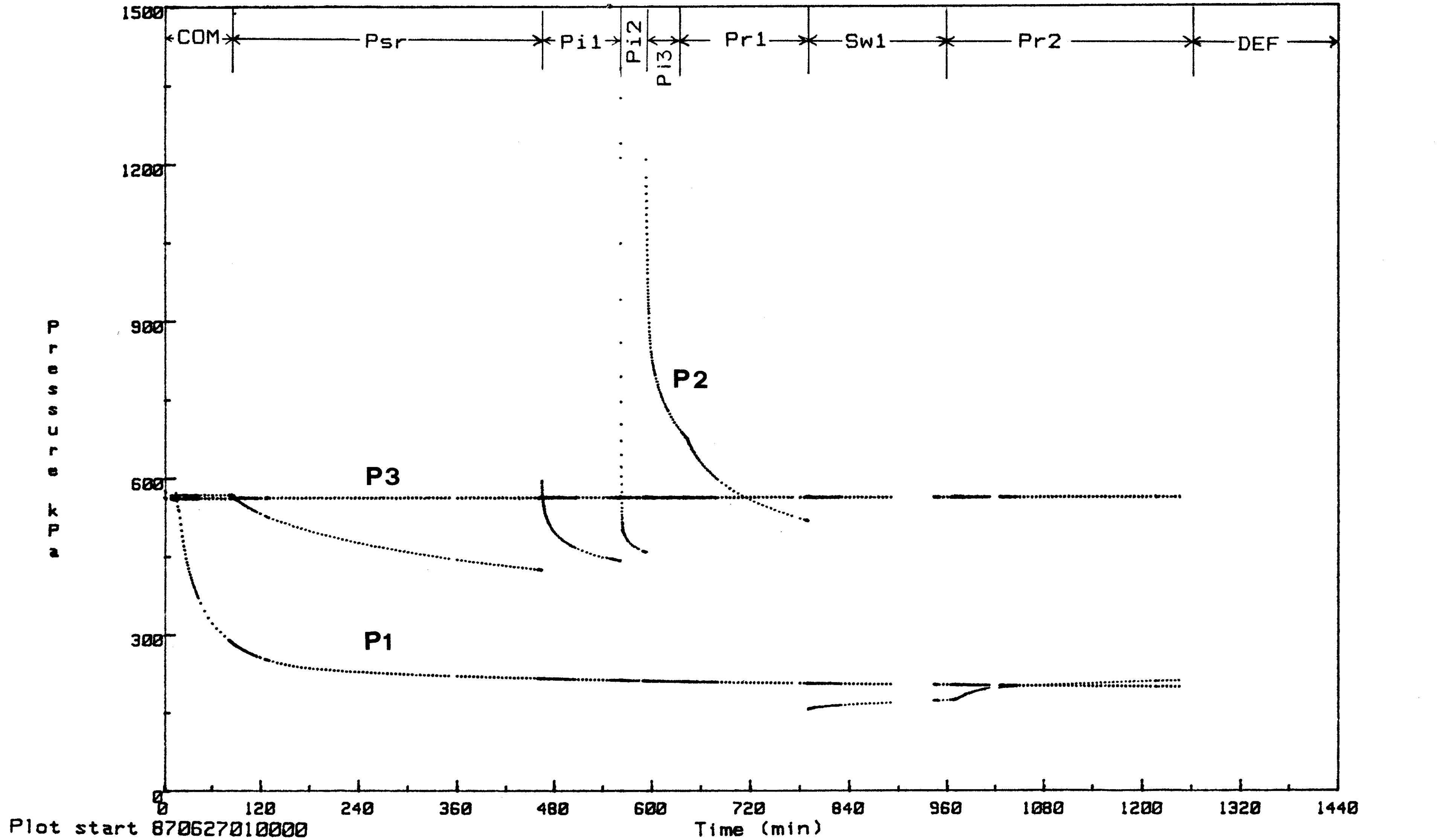
The hydraulic head value corresponding to a pressure of 250 kPa is 462 m (asl), compared to the drilling gallery floor and Lake Uri levels of 494 and 433 m (asl), respectively.

Attempts to bound the data with a single set of parameter values were not successful. The Psr and Pi1 events were able to be bounded using hydraulic conductivity values between 1e-12 m/s and 1e-11 m/s at a storativity value of 1e-5. However, values as high as 1e-10 m/s were not adequate to generate the flow observed during Sw1. No consistent paramer values bounded all the test data.

The interval responded as if it had either a positive skin effect that was reduced during the underpressuring of Sw1, or, a limited size and extent. A positive skin effect could account for the slower response during the pulse tests compared to the flow period. This assumes that the underpressure caused the borehole wall 'invasion' was overcome when it was subjected to the underpressure. A skin developed earlier during drilling would also have limited the extent to which the borehole history pressures were transmitted away from the wellbore. This could account for the slower pressure buildup response and the lower Pr2 end pressure compared to the pulse test end pressure values.

A limited extent reservoir could account for the continually increasing end pressures following each injection period, and the lower pressures at the end of the slug flow and final buildup event. Fluid released from storage could account for the flow amount during Sw1.

The interval did not respond like the model used to assess it's characteristics. At this time, without additional more detailed analysis, either of the two above conditions are possible.



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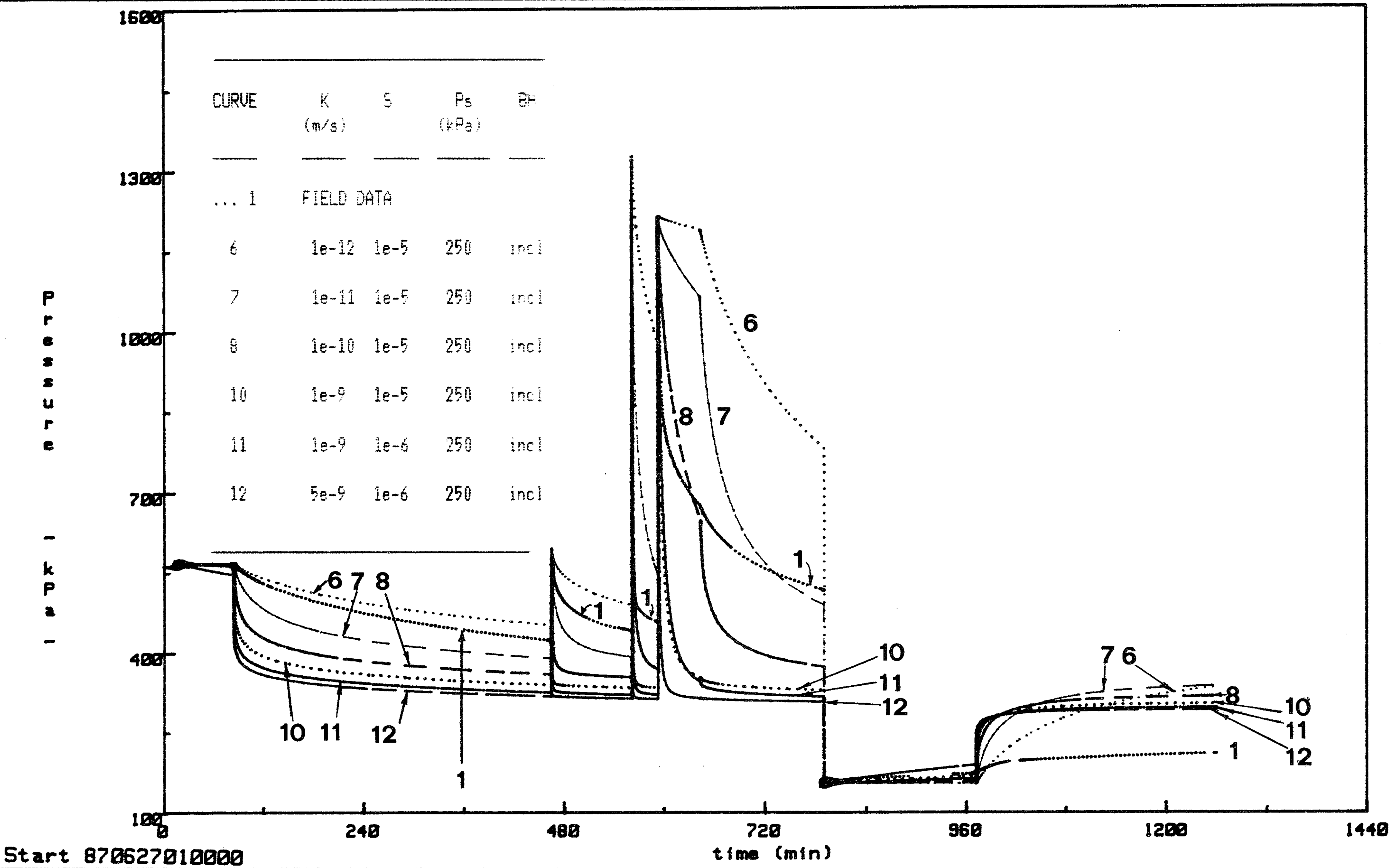
PRESSURE SEQUENCE PLOT - HGB/68.7D



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EXAMPLE SIMULATION - HGB/68.7D

B10. APPENDIX B10: INTERVAL HGB/76.3D

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 73.0 m and 78.6 m along the inclined borehole, respectively. This corresponded to vertical depths of 54.2 and 59.2 m, respectively. The P2 transducer was at a vertical depth of 52.3 m. Testing details are included in NIB 88-03, Section D.

B10.1 HYDROGEOLOGICAL SETTING

The upper 3 m interval consisted of a grey, massive marlstone with few identifiable fractures. RQD was 100 percent in this part of the interval. The lower part of the interval consisted of fine clay and brecciated rock layers. About 30 open fractures, all with apertures of less than 2 mm occurred in this lower part. RQD was 80 percent in the lower part.

This interval was the first detailed test following the screening tests. It covered the upper part of the 82.5D screening interval. This interval had indicated hydraulic conductivity values on the order of 1e-9 to 1e-8 m/s . Packer seats were selected to cover the borehole enlargement in the 82.5 interval which showed a diameter of 111 mm over a distance of about 1.7 m on the caliper log.

B10.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging,
3. Run-in of the testing equipment,
4. Screening tests 82.5D, 62.5D, and 42.5D, and,
5. Changing of straddle, run-in of equipment.

Potential inflow conditions lasted for about 154 hours.

B10.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B10.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Deflation	DEF

B10.3.1 Interval Response

Testing began with a 70 minute compliance period during which time there was no change in the fluid level at the top of the tubing. The Psr lasted 259 minutes. The pressure increased by 37 kPa, likely in response to continued packer compliance and a relatively tight interval. The final Psr pressure was 670 kPa.

Pi1 was done using the FAV and only recovered by about 60 percent in 172 minutes to a final pressure of 763 kPa. At this point, it was evident that this interval did not represent the zone that contributed to the HGB/82.5D interval response. Testing was terminated.

B10.3.2 Annulus Response

The pressure remained stable at about 618 kPa during the testing period.

Fluid was added to the tubing string to ensure that the FAV was closed. Some spillage may have occurred.

However, periodic additions to the annulus to maintain the level full were made during that time. The total volume added was less than 1 litre.

B10.3.3 Bottomhole Response

The P1-line surface valve was closed at the beginning of inflation and the pressure increased in response to packer squeeze. The valve was opened after inflation in an attempt to have the P1 line act as a piezometer tube. The pressure decreased in a consistent fashion and was at a final value of 352 kPa when testing was terminated.

B10.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 6 kPa over the 9 hour testing period.

B10.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.9°C and 17.1°C. The surface probe temperature varied between 19.8°C and 20.2°C.

B10.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B10.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The pulse test analysis indicated a conductivity values of about $1e^{-13}$ m/s.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B10.2. The increasing pressure during the Psr was assigned a series of increasing constant pressures to match the trend. In this manner, the Pi1 event data could be bounded.

No value of static pressure could be determined from the testing for this interval since the zone response was too tight. However, a value of 250 kPa had been relatively well documented for the HGB/82.5D interval. An initial value of 290 kPa was used for this interval.

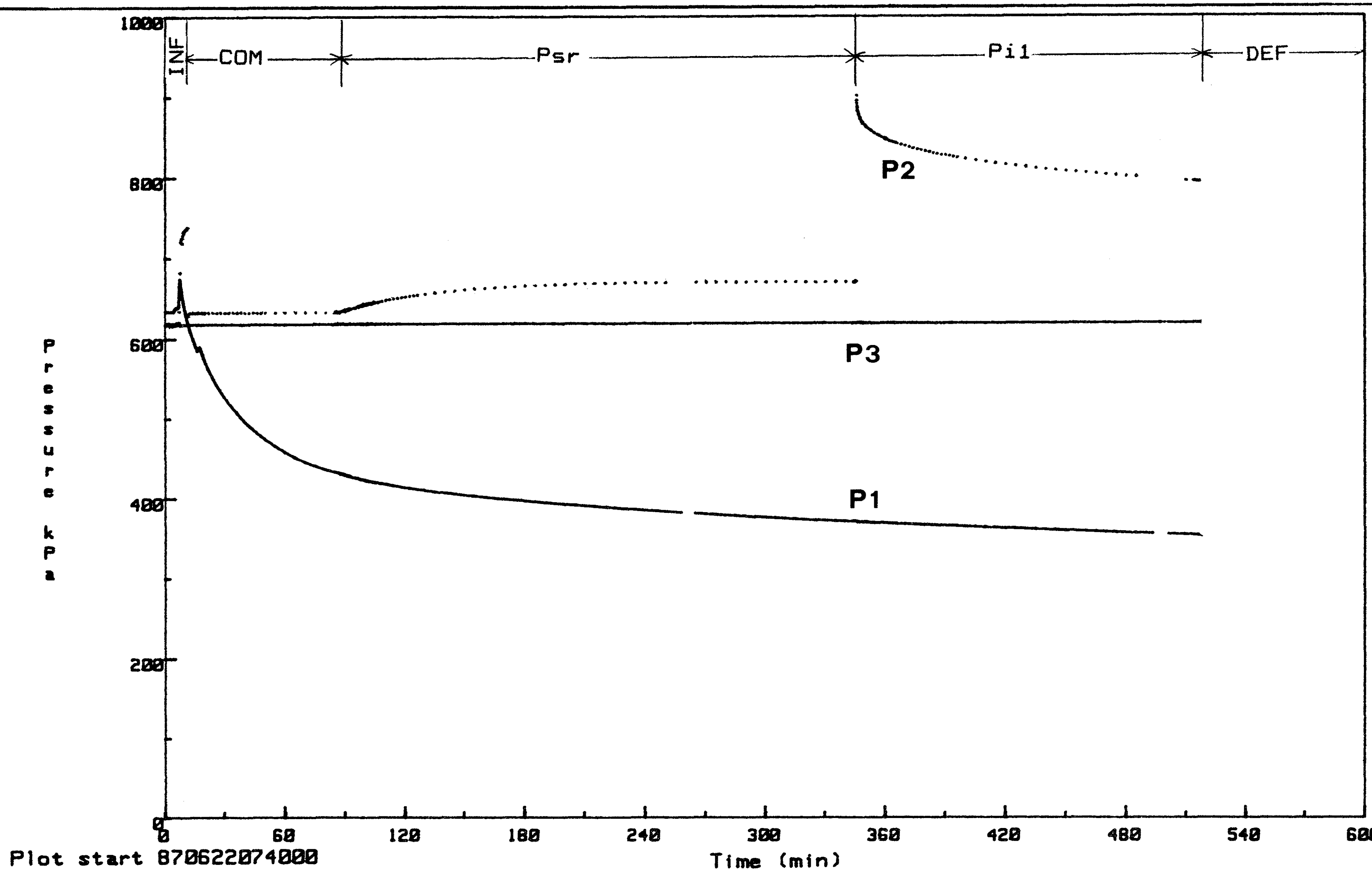
B10.4.2 Results

Borehole history pressures were between 600 and 625 kPa during most of the borehole history period which had lasted just over 6 days. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the low permeability in the zone meant that that a value of static pressure considered representative of interval conditions would have to be estimated from other borehole data.

The pressure value of 290 kPa used was consistent with testing values in the HGB/82.5D screening interval. However, since only one event could be effectively bounded, the analysis was not considered adequate to confirm the pressure results. Based on the results from other intervals, a reasonable static pressure value would be between 240 and 340 kPa.

Hydraulic head values corresponding to pressures of 240 and 34 kPa are 55 to 465 m (asl), compared to the drilling gallery floor and Lake Uri levels of 494 and 433 m (asl), respectively.

The data was bounded with a hydraulic conductivity between 1e-13 and 1e-12 m/s over the reasonable range of storativity from 1e-6 to 1e-3.



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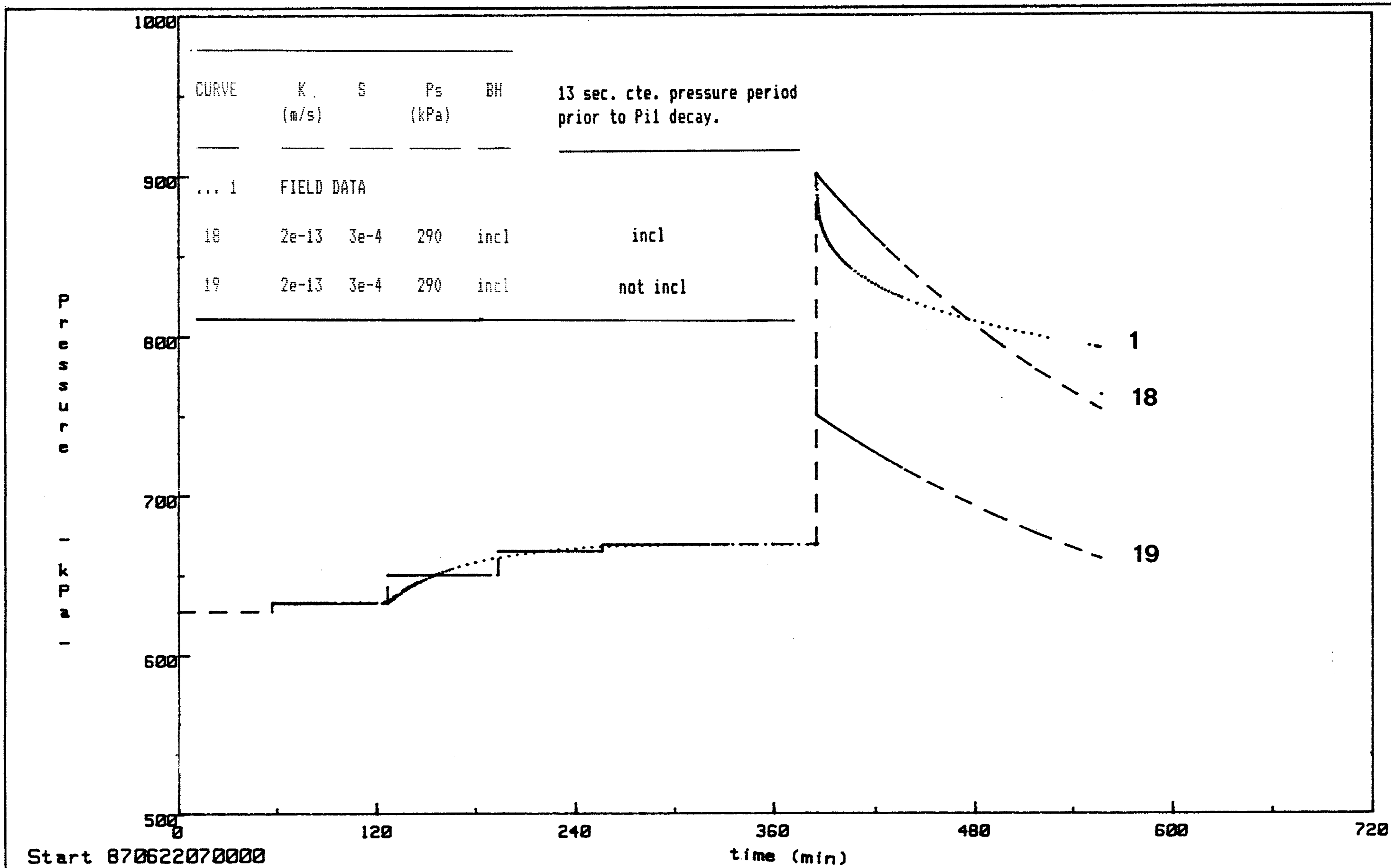
PRESSURE SEQUENCE PLOT - HGB/76.3D



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EXAMPLE SIMULATION - HGB/76.3D

B11. APPENDIX B11: INTERVAL HGB/82.5D

This interval was tested using a double straddle packer assembly with a length of 19.0 m. The upper and lower packer seats were at lengths of 73.0 m and 92.0 m along the inclined borehole, respectively. This corresponded to vertical depths of 54.2 and 68.6 m, respectively. The P2 transducer was at a vertical depth of 52.3 m. Testing details are included in NIB 88-03, Section A.

B11.1 HYDROGEOLOGICAL SETTING

The interval consisted of a massive grey clayey marlstone with fine fractures which were occasionally mineralized. RQD varied from 60 to 100 percent.

This interval was the first test conducted and the first of three screening intervals tested in HGB. Packer seats were selected to cover the deepest part of the borehole accessible with the tool tailpipe (stickdown) and the available packer seats. The caliper log indicated four specific borehole enlargements to a maximum of 111 mm.

B11.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment.

Potential inflow conditions lasted for about 85 hours.

B11.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B11.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Slug injection 1	Si1
6. Pressure recovery 1	Pr1
7. Pulse injection 2	Pi2
8. Pulse injection 3	Pi3

9. Constant rate injection test Qcr
10. Pressure recovery 2 Pr2
11. Pulse injection 4 Pi4
12. Pulse injection 5 Pi5
13. Slug injection 2 Si2
14. Pressure recovery 3 Pr3
15. Deflation DEF

Events 11 through 14 were done to evaluate the performance of various configurations of the injection equipment. No analysis of these data relative to the hydraulic characteristics of the interval has been included.

B11.3.1 Interval Response

Testing began with a 41 minute compliance period during which time the fluid level fell by about 4.5 m in the tubing with a final pressure of 580 kPa. The Psr lasted about 6 hours. The pressure decreased consistently to a value of 292 kPa and was still declining.

Pi1 was done using the FAV and recovered by 100 percent in 78 minutes. The tubing was filled with water and the FAV opened to allow flow into the interval. The slug flow event, Si1, lasted about 3 hours during which time the pressure decreased from 584 to 395 kPa. The FAV was closed to monitor the shut-in recovery, Pr1, for a period of 202 minutes. The pressure decreased by an additional 102 kPa to a final shut-in value of 293 kPa and was still decreasing slowly. A second pulse test, Pi2, was done using the FAV with an initial overpressure of 340 kPa. A third pulse test, Pi3, was done using the FAV with a higher initial overpressure of 494 kPa. It recovered fully and the pressure decrease continued to a value of 284 kPa after about 118 minutes. Larger initial overpressures were attempted on each of the three pulse tests. However, they were not able to be achieved due to equipment difficulties and the relatively rapid response of the interval.

The high capacity pump was connected between the HVT and the wellhead to start the injection testing. The HVT was being used as a reservoir for the pump. However, when the downhole valve was opened, water flowed through the pump that had not yet been started, at a rate of about 4 litres/min. Once the pump was started, the rate was able to be controlled. Periodic adjustments were made to limit and maintain an average rate at about 1.1 litre/min. Wellbore storage lasted until about 40 minutes into the Qcr event. Qcr lasted a total of 80 minutes during which time the pressure in the interval was increased from 284 to 1394 kPa.

The FAV was closed to monitor the final testing activity recovery, Pr1. Pressure decreased to 319 kPa after about 4 hours and was still declining slowly.

The remaining time opposite the interval was spent evaluating techniques for further injection testing.
The desired higher initial overpressures were finally achieved but pre-pulse open period times of about 60 seconds were required to achieve these pressures.

B11.3.2 Annulus Response

The pressures decreased by about 2 kPa during testing.

B11.3.3 Bottomhole Response

The P1-line surface valve remained closed for most of the testing. Initially, the bottomhole pressure increased by 44 kPa to 687 kPa, likely in response to packer squeeze. It declined slowly after that in an apparent linear manner.

The valve was opened about 14 hours into the testing (Point A, Figure B11.1) at which time the pressure increased. It then decreased by 5 kPa over the following 7 hours and unexpectedly fell by about 100 kPa (Points B to C, Figure B11.1). It decreased slowly after that for the remaining part of the testing. The final bottomhole pressure was 520 kPa.

B11.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 130 kPa over the 22 hour testing period.

B11.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.7°C and 17.3°C. The surface probe temperature varied from 19.8°C to 20.0°C.

B11.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B11.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The Pi1 event responded faster in the first minutes than during the rest of the event. Accordingly, the type curve match of the early time was not indicative of the late time data. The early time data indicated conductivity values on the order of 4e-10 m/s. The Si1 analysis matched well with the type curves and resulted in a value about one order of magnitude higher. The type curve matches of the Pi2 and Pi3 events again yielded lower conductivity values than the injection event. Straight-line horner-type analyses of the Pr1 and Pr2 recovery periods following the Si1 and Qcr events yielded conductivities on the order of 2e-9 m/s.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B11.2. The open periods prior to the stat of each pulse test were not included in the simulations of the interval response. Instead, the emphasis was on bounding the slug injection and recovery, and the final Qcr and Pr2 events.

An apparent static pressure could be extrapolated from the end pressures of the different shut-in responses. These all indicated value of less than 290 kPa. However, this apparent value, based on the visual analysis of the data did not include the almost four days of higher borehole history pressures. A value of 250 kPa was initially used in the simulations based on the interval response and the borehole history.

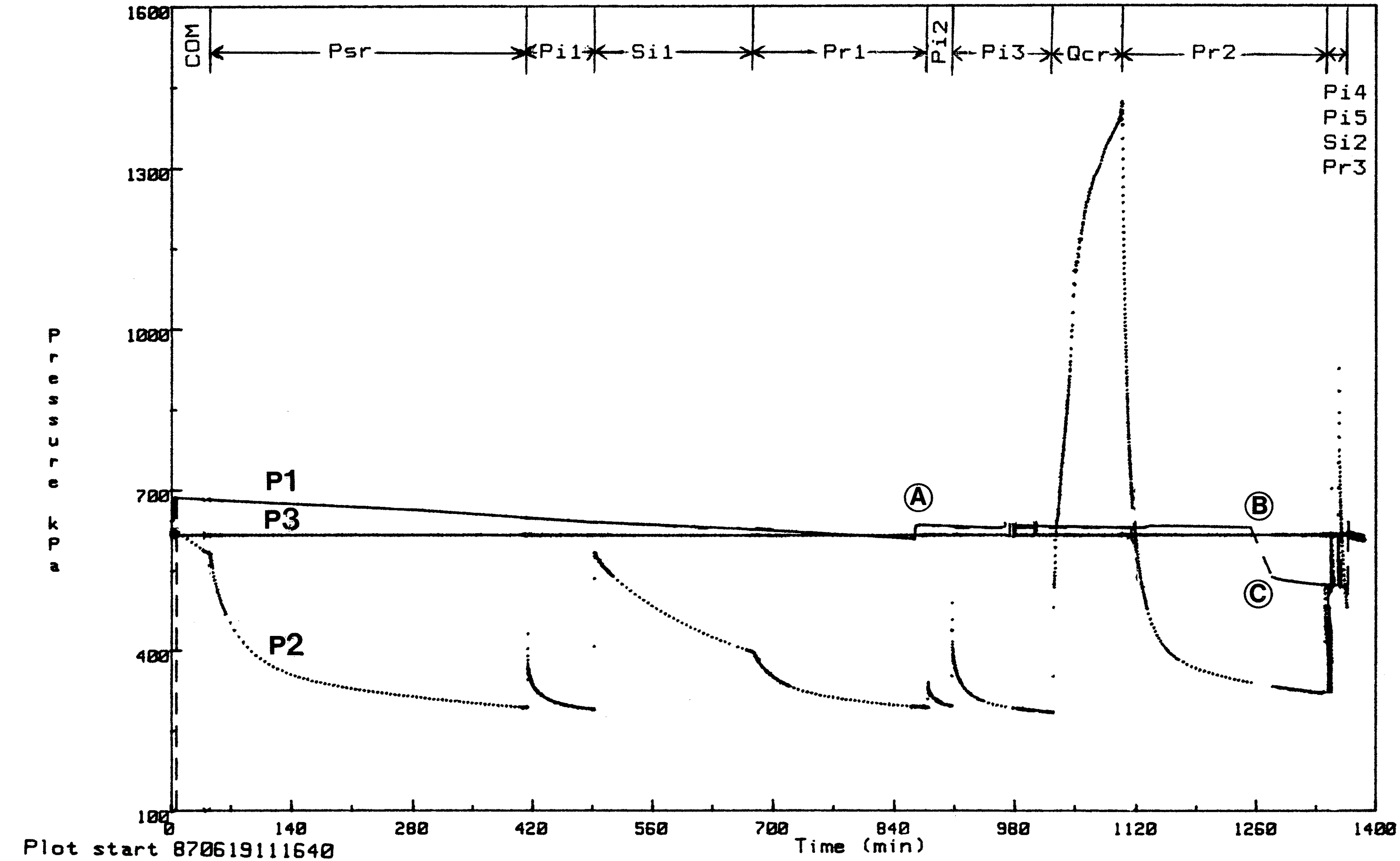
B11.4.2 Results

Borehole history pressures were between 425 and 625 kPa for most of the 3.5 day borehole history period. The drilling and annulus fluid level during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing.

The pressure value at the end of the shut-in events indicated static pressure should be less than about 280 kPa. Results of the analysis indicate a value of between 240 and 260 kPa is reasonable for the interval when the borehole history effect is included. These values correspond to hydraulic head elevations of between 455 and 457 m (asl), compared to the drilling gallery floor and Lake Uri elevations of 494 and 433 kPa.

The data were able to be bounded with hydraulic conductivity values between 1e-9 and 1e-8 m/s over a range of storativity from 1e-5 to 1e-3.

The anomalous early time pulse test responses may have been the result of longer open periods at the start of the test than the assumed instantaneous conditions used in the analysis assumptions. Further a gas in the closed chamber or packer compliance, or other, different wellbore storage conditions such as a larger wellbore volume could account for part of this difference. Skin effect could also cause early time responses different than the late time data. In this instance, however, the initial conditions, were not as critical in affecting analysis of the slug-type responses which characterize the formation to a further distance away from the wellbore. The interval data were well bounded for those events.



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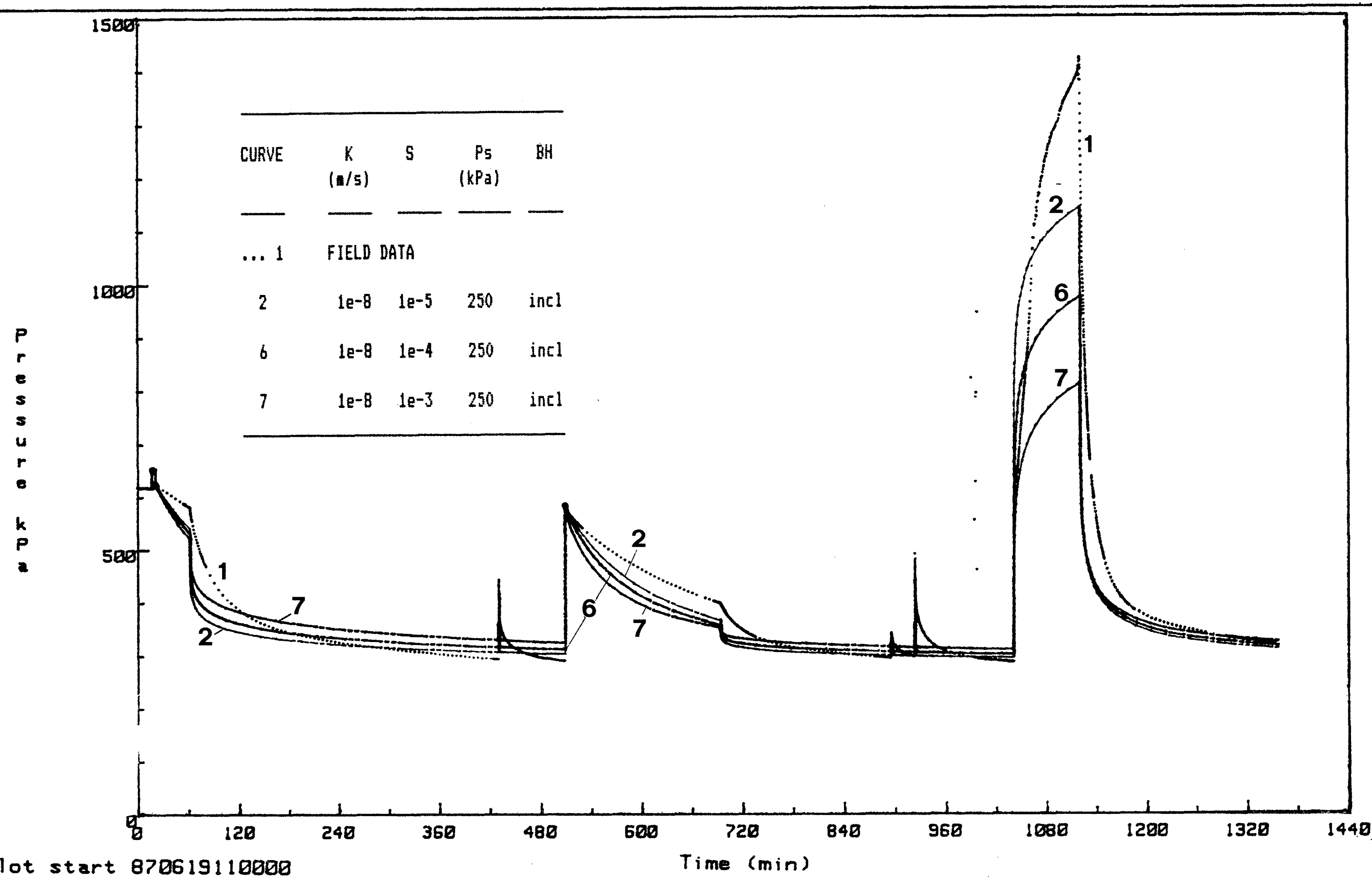
PRESSURE SEQUENCE PLOT - HGB/82.5D



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EXAMPLE SIMULATION - HGB/82.5D

B12. APPENDIX B12: INTERVAL HGB/83.3D

This interval was tested using a double straddle packer assembly with a length of 6.6 m. The upper and lower packer seats were at lengths of 80.0 m and 86.6 m along the inclined borehole, respectively. This corresponded to vertical depths of 59.5 and 64.5 m, respectively. The P2 transducer was at a vertical depth of 57.6 m. Testing details are included in NIB 88-03, Section E.

B12.1 HYDROGEOLOGICAL SETTING

The interval consisted of a massive grey clayey marlstone with small scale folds and layering offsets. Fine fractures were occasionally mineralized. RQD was 100 percent.

This interval was the second of the two detailed tests conducted in the HGB/82.5D screening interval. The other detailed test in the screening interval, HGB/76.3D, did not have adequate permeability to account for the HGB/82.5D response. Packer seats were selected to cover the deeper part of the screening interval.

B12.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in of the testing equipment,
4. Screening tests 42.5D, 62.5D and 82.5D,
5. Changing of straddle, run-in of equipment, and
6. Detailed test 76.3D.

Potential inflow conditions lasted for about 154 hours.

B12.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure B12.1, included:

1.	Inflation	INF
2	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Pulse injection 1	Pi1
5.	Slug injection 1	Si1

6. Pressure recovery 1 Pr1
7. Slug withdrawal 1 Sw1
8. Sampling events SAM
9. Deflation DEF

Sampling events consisted of 15 activities including the initial attempt to use the squeeze pump, 13 swabbing and flow recoveries and a final sample recovery using the squeeze pump and pressurized sampling vessels. The pressure responses associated with these activities are shown in Figure B12.2. No analysis was done of the sampling activity pressure data.

B12.3.1 Interval Response

Testing began with a 92 minute compliance period during which time the fluid level fell by about 6 m in the tubing to a final pressure of 606 kPa. The Psr lasted about 323 minutes. The pressure decreased consistently to a value of 387 kPa and was still declining.

Pi1 was done using the FAV and recovered by 100 percent in 36 minutes. The tubing was filled with water and the FAV opened to allow flow into the interval. The slug flow event, Si1, lasted about 4 hours during which time the pressure decreased from 670 to 533 kPa. The FAV was closed to monitor the shut-in recovery, Pr1, for a period of 146 minutes. The pressure decreased by an additional 132 kPa to a final shut-in value of 383 kPa and was still decreasing slowly.

Most of the water was removed from the tubing in preparation for the Sw1 event. The withdrawal test was done to evaluate at what rate the interval would yield fluid to the wellbore. The FAV was opened and the interval exposed to an initial pressure of 176 kPa. The event lasted 252 minutes during which time the pressure increased by 135 kPa to a final flowing pressure of 311 kPa.

At this point, NAGRA decided to attempt to sample the fluid from the interval. Sampling continued for 83 hours.

B12.3.2 Annulus Response

The pressures decreased by about 4 kPa during testing. About 6 litres of water were added over a 45 hour period to maintain the annulus level full.

B12.3.3 Bottomhole Response

The P1-line surface valve remained closed for all of the testing and sampling.

Communication occurred between the bottomhole zone and the interval over most of the testing. This was initially suspected to be occurring when the similarity in the P1 and P2 pressures developed during Psr. The trend was confirmed during the Sw1 event and continued during the sampling activities.

Communication was through the rock around the bottom packer seal, as opposed to along the borehole wall.

B12.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It increased by about 100 kPa over the 18 hours of testing. It was increased to 6800 kPa at that time to attempt to seal the communication between the interval and the bottomhole zone. It increased an additional 360 kPa during the sampling period.

B12.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 16.5°C and 17.2°C. The surface probe temperature varied from 19.9°C to 20.0°C.

B12.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

B12.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The Pi1 event matched well with the type curve indicating a conductivity of about 2e-10 m/s. The Si1 and Sw1 data also matched well with the type curves but resulted in a value about two orders of magnitude higher. Straight-line horner-type analyses of the Pr1 event the Si1 event yielded conductivity on the order of 7e-9 m/s.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig B12.3.

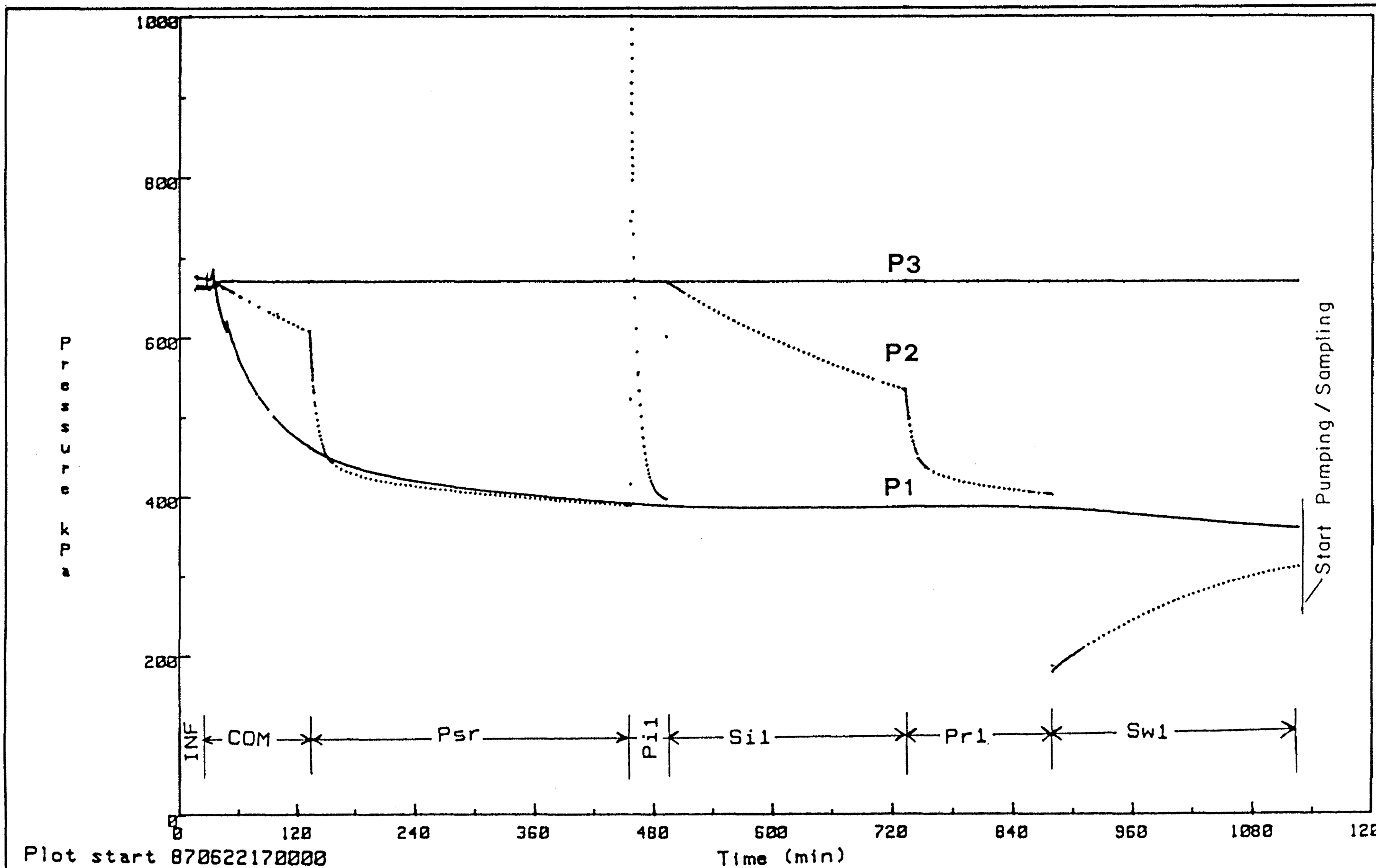
An apparent static pressure could be extrapolated from the end pressures of the different events. These indicated a value of between 360 and 390 kPa. However, this apparent range, based on the visual analysis of the data did not include the almost 6.5 days of higher borehole history pressures. A value of 370 kPa was initially used in the simulations based on the interval response and the borehole history.

B12.4.2 <u>Results</u>

Borehole history pressures were generally between 350 and 700 kPa during the 6.5 day borehole history period. The drilling and annulus and bottomhole fluid pressures during the prior testing affected the pressures in the vicinity of the borehole prior to and during testing.

The pressure value at the end of the shut-in events indicated static pressure should be between 360 and 390 280 kPa. Results of the analysis indicate a value of between 350 kPa is reasonable for the interval when the borehole history effect is included. This corresponds to a hydraulic head elevation of about 461 m (asl), compared to the drilling gallery floor and Lake Uri elevations of 494 and 433 kPa.

The data were able to be bounded with hydraulic conductivity values between 5e-9 and 1e-8 m/s over a range of storativity from 1e-6 to 1e-4.



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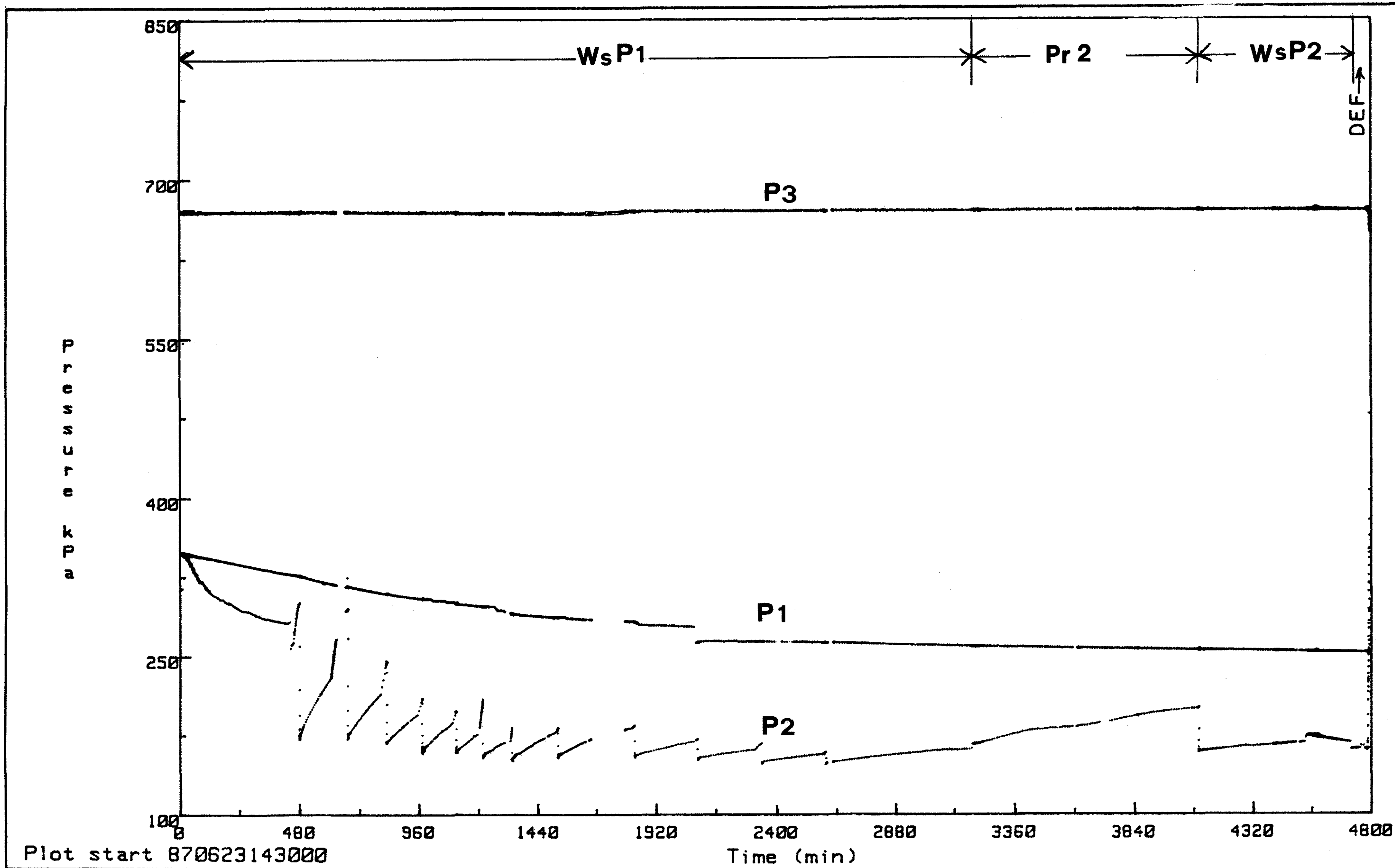
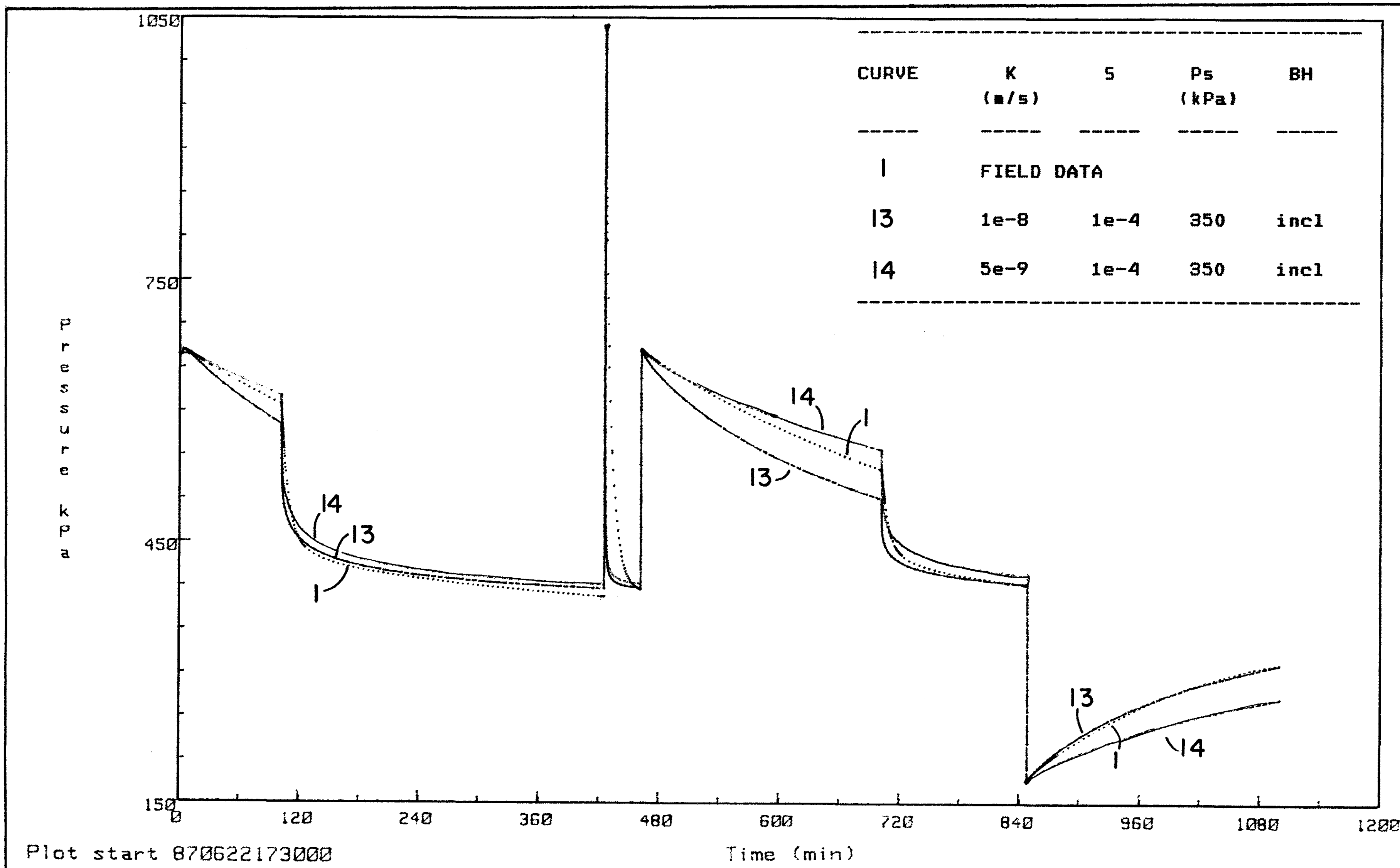
PRESSURE SEQUENCE PLOT - TESTING - HGB/83.3D



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B12.2

PRESSURE SEQUENCE PLOT - SAMPLING - HGB/83.3D



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	B12.3

EXAMPLE SIMULATION - HGB/83.3D

APPENDIX C:

SA INTERVAL SUMMARIES

C1. APPENDIX C1: INTERVAL SA/100.2S

This interval was tested using a single packer assembly. The open hole section tested had a length of 5.9 m. The upper packer seat and total borehole depth were at 97.2 and 103.1 m, respectively. Testing details are included in NIB 88-04, Section A.

C1.1 HYDROGEOLOGIC SETTING

The interval consisted of a gray marlstone with an RQD of between 10% and 50%. Fracture density increased in the lower half of th interval corresponding to the lower RQD. The fractures within this interval were recorded as either filled or closed.

This interval was the first interval to be tested in the borehole. Drilling was stopped shortly after fluid losses of about 600 litres had occurred at a depth of about 101.5 m. The two flow checks performed by GEMAG at depths of 101.7 and 103.1 m indicated relatively high conductivity. The pore volume associated with the test zone is thought to be associated with vugs in the rock possibly filled with gas at an earlier time. This could account for the fluid losses that occurred during drilling. The fluid losses may also, in part, be related to the overpressure at the bit face during drilling.

C1.2 BOREHOLE ACTIVITY SUMMARY

The activities opposite the interval prior to testing were:

1. Drilling through the interval,
2. Preparation of the borehole for logging and testing,
3. Geophysical logging of the borehole, and,
4. Run-in of the test equipment.

The borehole fluid level dropped naturally to about 40 m in the four hours after drilling stopped. All borehole history activities lasted about 45 hours. There was an overpressure and, therefore, potential inflow conditions from the borehole into the interval most of the time.

C1.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figures C1.1 and C1.2, included:

1.	Inflation	INF
2.	Compliance	COM
3.	Shut-in static recovery	Psr
4.	Slug Withdrawal 1	Sw1
5.	Pressure Recovery 1	Pr1
6.	Sampling Sequence 1	Sam1
7.	Clean-Up of Borehole	Clean-up
8.	Sampling Sequence 2	Sam2
9.	Sampling Sequence 3	Sam3
10.	Deflation	Def

C1.3.1 <u>Interval Response</u>

The interval response was monitored by both the P1 and P2 transducers. There was no connection from surface to the interval since the P1 to surface line was disconnected. Mechanical differences in the P1 and P2 transducer porting and air trapped in the P1 line accounts for their pressure differences.

Testing began with a 81 minute compliance period during which time there was an 81 kPa decrease in pressure corresponding to a fluid level fall in the tubing. The final pressure was 627 kPa. Psr lasted about 4 hours. The response was not as expected. After an initial drop of about 25 kPa shortly after closing the FAV, the shut-in response had a similar rate of decrease as had occurred during compliance. The total pressure falloff was about 90 kPa to final value of 540 kPa.

The first diagnostic test was a slug event due to the expected permeability in the interval. Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 184 kPa at the start of SW1. An underpressure was used to see if fluid would flow up into the tubing. A consistent and steady increase of 240 kPa was recorded during 45 minutes at which time the pressure was 423 kPa.

The FAV was closed and the final pressure buildup was monitored. Pr1 lasted 49 minutes. The pressure increased rapidly at the beginning of the shut in and then continued to rise at a slower rate. The final pressure was 461 kPa and was increasing slowly at the end of testing in the interval.

After completion of testing, emphasis was placed on removing the drilling fluid and recovering a representative sample. Drilling fluid was removed first by closing the FAV and swabbing out the water in the tubing. This cycle was repeated on one hour intervals during Sam1. The following day, the interval was subjected to 8 to 9 bar overpressures in an attempt to increase formation flow (clean-up). Water was driven into the interval and surged back into the tubing. However, the flow rate did not increase. Swabbing intervals were extended to 2 hours during Sam2.

Tracer concentration was monitored by GEMAG. It dropped to about half the original concentration at the end of Sam2 and it was agreed that given the time criteria, swabbing should end to allow maximum recovery of the formation in preparation for the final sampling (Sam3).

Sampling began 10 hours later with an available head of about 6 m. The first samples were taken using two AECL sample vessels and about one litre of pressurized fluid was recovered. A second sample was taken for dissolved oxygen analysis using the AECL squeeze pump.

A total of about 430 L of fluid was retrieved during all sampling activities.

C1.3.2 Annulus Response

Annulus pressure was stable. Pressures values ranged between about 701 kPa and 712 kPa.

C1.3.3 Packer Response

Packer pressure decreased by about 430 kPa despite being connected to a constant pressure source at surface. Deflation required pumping fluid into both the interval and the annulus since the fluid level in the packer inflation line was at ground surface.

C1.3.4 Temperature Response

Temperatures at sensor depth varied from about 18.0°C to 18.2°C. The surface temperature at the wellhead varied from about 22.0°C to 22.3°C.

C1.4 INTERPRETATION AND RESULTS

This interval was selected for testing and sampling based on the sudden loss of about 600 litres of drilling fluid. The drilling history is certain. Drilling pressures likely created inflow conditions that may have influenced the formation response. It is also possible that the drilling activity created a skin effect in the vicinity of the borehole.

C1.4.1 Analysis procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer level. No temperature effect occurred.

Early time plots were made for all events to extrapolate the initial conditions of each event. The fact that the pressure had not stabilized prior to the start of Sw1 meant that the initial conditions for the slug test were not rigorously correct. There was adequate flow during Sw1 to justify making diagnostic early-time log-log plots of both the Sw1 and Pr1 events. Results of these plots indicated that the flow during Sw1 likely reached radial flow conditions as did the subsequent Pr1 shut-in response. This implied that the analyses in the QLR were reasonable providing that any skin or borehole history effects did not impact the results.

The interval report analysis used the GLIMPSE model to attempt to bound the interval data response during the testing activities. Responses during the sampling exercise were not included.

The rate of pressure change at the end of the COM and Psr events was similar. This consistency with or without borehole conditions could not be bounded. Instead, both events were assigned constant pressure values to resemble the actual data (Figure C3.3) and bounding was therefore restricted to the last two events.

The static pressure value that was used for bounding was based on the extrapolated end pressure from Pr1 event. This biased the analysis approach. Selecting this value implied that there was no residual borehole history pressure affecting the testing at the time of this event. In light of the response towards the end of testing, it is likely that the interval did have a lower static pressure value. At the time of testing, however, both the Sw1 and Pr1 events were responding to this static pressure.

The contributing thickness was assumed to be full interval length between the packers. The range of hydraulic conductivity used in the attempts to bound the data was from 9e-8 m/s to 2e-7 m/s at storativity values from 1e-7 m/s to 1e-3.

Initial attempts were made to bound the data using the values determined from the Sw1 and Pr1 as documented in the QLR. The unreasonably low storativity value determined for the Sw1 event did not allow any flow to occur, with or without borehole history included. A more realistic range of storativity was then considered.

Attempts to bound including borehole history were not successful using a static equal to the Pr1 end pressure value. No matter what combination of values was used, the Sw1 and Pr1 events could not be consistently bounded. It was therefore decided to simulate the COM and Psr events as constant pressure steps, and thus analyse the Sw1 and Pr1 events with the wellbore simulator. Excluding borehole history when matching only the last two events, however, is reasonable and does provide a realistic range for K and S. Figure C3.3 illustrates the bounding using a K value of 1e-7 m/s and variable storativity.

Possible rationale for excluding borehole history was that a skin effect limited the extent to which borehole history effected the formation. In that case, the COM and Psr stages of the test may have been responding to the conditions with this skin zone whereas the SW1 and Pr1 events would reflect the relatively undisturbed hydraulic properties of interval.

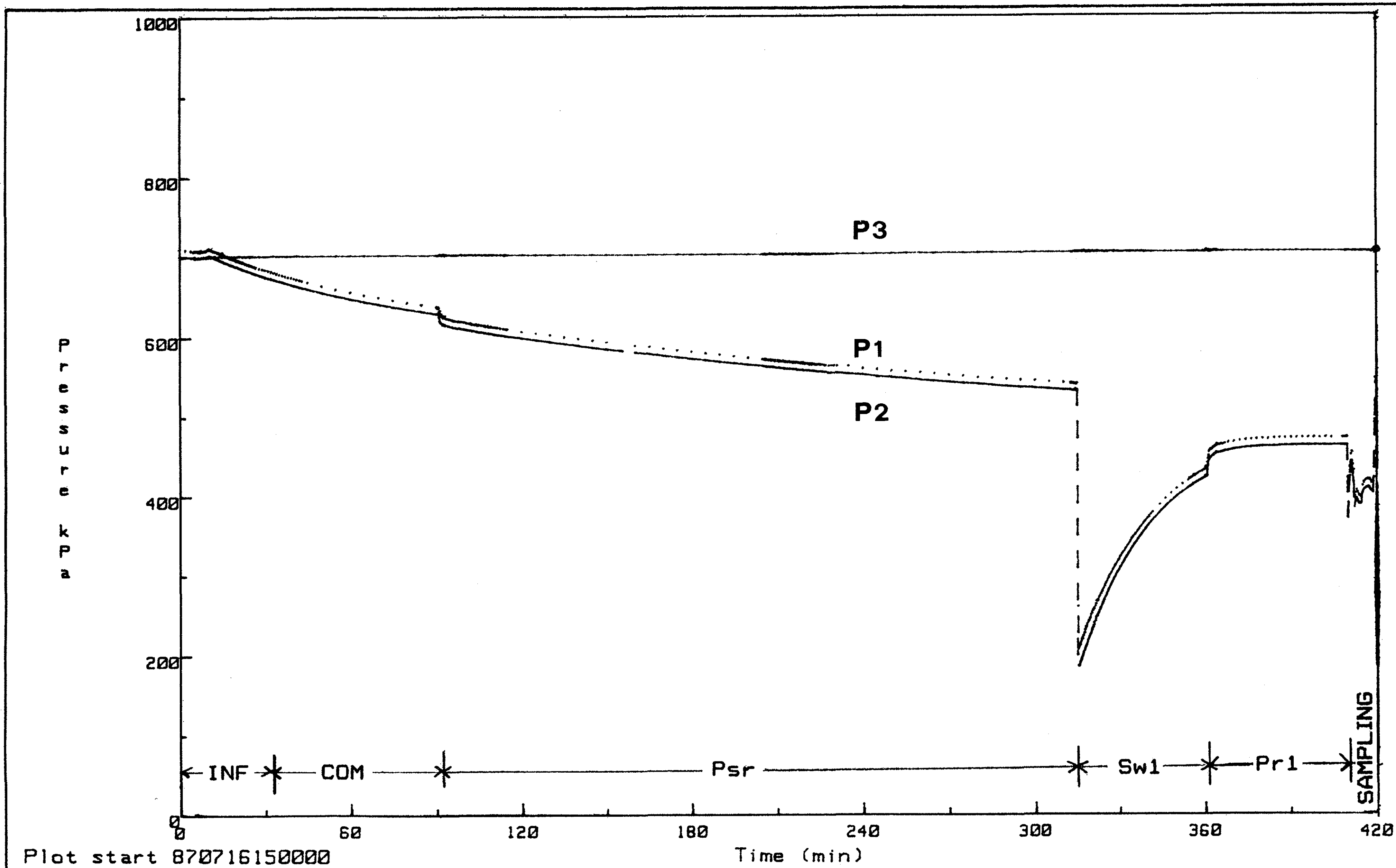
C1.4.2 Results

The inflow associated with the drilling and open borehole did affect the formation being tested. The first part of the interval testing was responding first, to the influence of these activities, and, second, to the possible presence of a skin effect developed during this time.

The static pressure for the interval is less than 460 kPa. The hydraulic head for this pressure is at an elevation of about 433 m similar to the reported Urner Lake level of 433 m. However, based on the response flowing testing, which illustrated responses on the order of 250 to 300 kPa, the hydraulic head could be below the lake level.

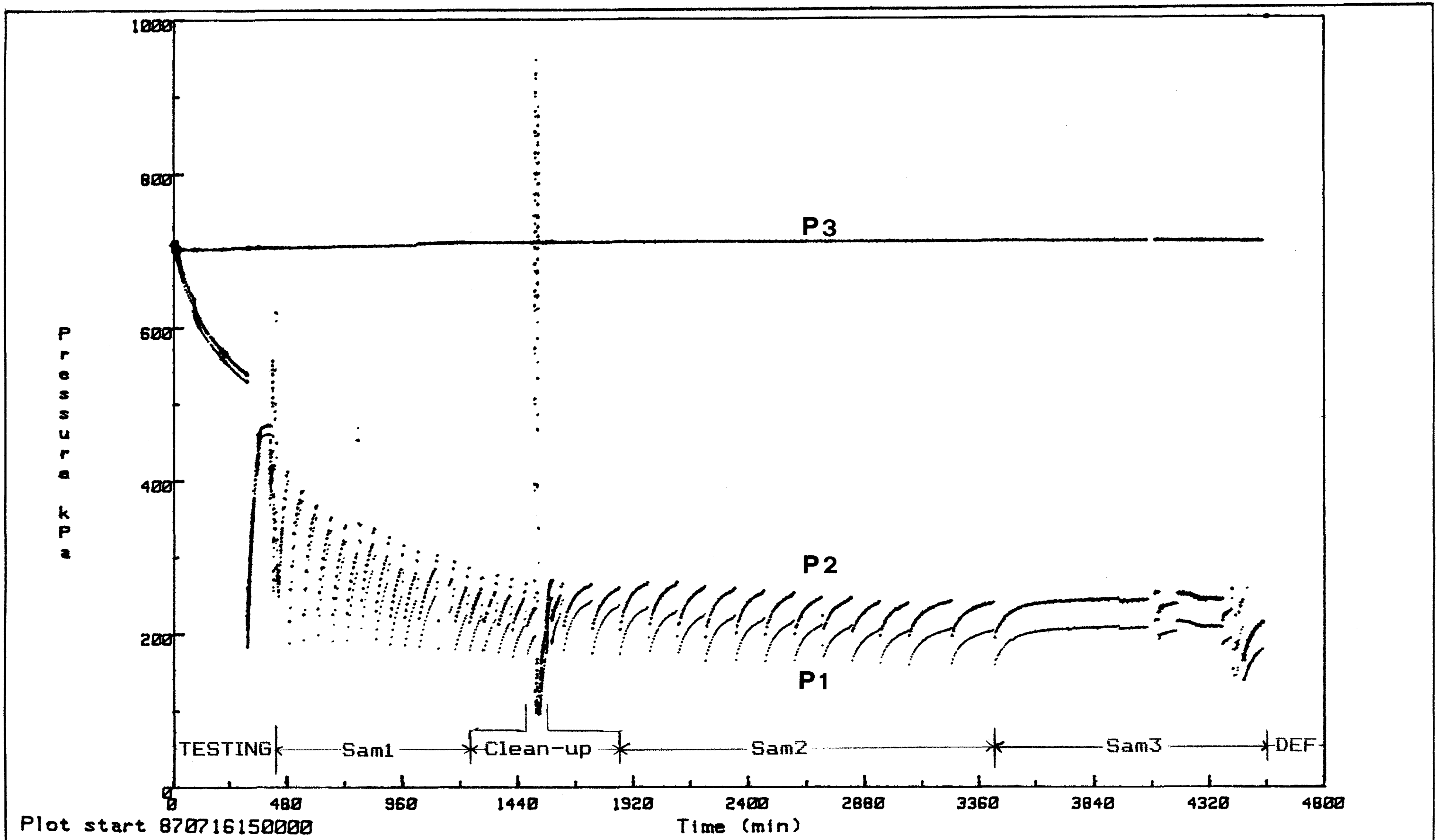
The storativity value of about 2e-13 associated with the SW1 analysis in the QLR using type curve solutions, however, is not within expected formation value ranges, and may reflect the presence of a positive skin.

By focusing the simulation and bounding of only the last two test events (SW1, Pr1), the data were bounded with a conductivity of about 1e-7 m/s, and storativity of between 1e-6 and 1e-3 and a static pressure of 460 kPa. The K value and S range is reasonable. The pressure value, as discussed above, may be too high.



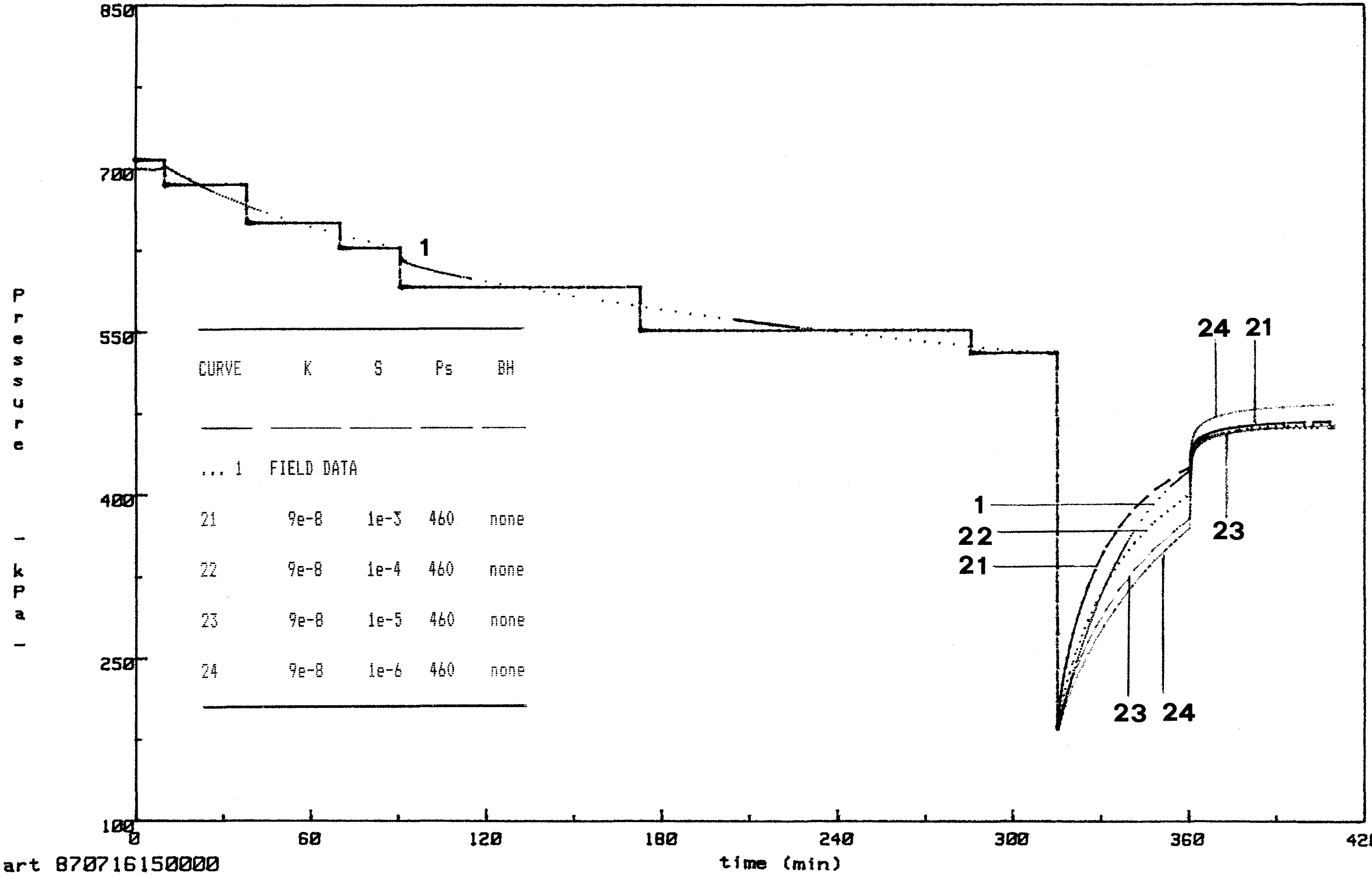
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C1.1

PRESSURE SEQUENCE PLOT - TESTING - SA/100.2S



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C1.2

PRESSURE SEQUENCE PLOT - SAMPLING - SA/100.2S



CURVE	K	S	Ps	BH
... 1	FIELD DATA			
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22	9e-8	1e-4	460	none
23	9e-8	1e-5	460	none
24	9e-8	1e-6	460	none

Start 870716150000

NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | C1.3

EXAMPLE SIMULATION - SA/100.2S

C2. APPENDIX C2: INTERVAL SA/137.0D

This interval was tested using a double straddle packer assembly with a length of 19.1 m. The upper and lower packer seats were at 127.5 m and 146.6 m, respectively. Testing details are included in NIB 88-04, Section F.

C2.1 HYDROGEOLOGICAL SETTING

The interval consisted of alternating massive and layered marlstone with silty and brecciated zones. Two open fractures occurred at 134 and 139 m. RQD varied from 40 to 100 percent.

This was the fourth detailed interval tested after completion of drilling. The interval caliper log showed an enlargement to a maximum of 132 mm at a depth of 144 m. The purpose of the testing was to attempt to determine a pressure between the SA/100.2S and SA/160.6S interval depths.

C2.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to 166m,
2. Run-in, testing 160.6S, and run-out,
3. Drilling to 300.2 m,
4. Geophysical logging and drilling to total depth,
5. Geophysical logging,
6. Run-in, testing 298.0D, 311.0D, run-out,
7. Changing straddle, run-in and test 196.5D1, and,
8. Run-out, repair the equipment and run-in.

These activities took place over almost 28 days prior to testing.

C2.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure C2.1, included:

1. Inflation	INF
2. Shut-in static recovery	Psr
3. Slug withdrawal 1	Sw1
4. Pressure recovery 1	Pr1
5. Deflation	DEF

C2.3.1 Interval Response

The tubing was run in dry and the FAV was kept closed during inflation. No compliance period was possible.

Testing began with a 15 hour Psr event during which time the pressure decreased from 2334 kPa, which occurred as a result of packer squeeze during inflation, to a final value of 671 kPa. The Psr event had been prolonged to see if the P2 pressure would fall below the P1 bottomhole pressure.

The FAV was opened and the zone subjected to an initial pressure of 179 kPa at the start of Sw1. An under-pressure was used to see if fluid would flow up into the tubing. The flowing pressure increased by 19 kPa during the 31 minute event to a final value of 198 kPa. The final recovery, Pr2, was monitored for 366 minutes during which time the pressure increased to 329 kPa.

The interval testing was terminated realizing the interval was too tight to obtain a well documented static pressure.

C2.3.2 Annulus Response

The pressure decreased by about 15 kPa during testing.

C2.3.3 Bottomhole Response

The P1 line to surface was disconnected downhole so there was no line hydraulics affecting the bottomhole response. The P1 pressure increased by about 400 kPa during inflation in response to packer squeeze. It decreased thereafter and stabilized at between about 800 and 815 kPa during most of the testing.

C2.3.4 Packer Pressure Response

The packer pressure was controlled at surface with a pressure regulator and nitrogen gas source. The pressure decreased by about 60 kPa during the 22 hours of testing.

C2.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 18.4°C and 19.3°C. The surface probe temperature varied from 21.2°C to 21.9°C.

C2.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures opposite the interval during drilling and the following borehole history activities likely influenced the formation response during testing.

C2.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The response of the Sw1 event was too small to evaluate accurately with type curves. The flow rate had varied and was irregular during Sw1. The horner-type analysis of Pr1 was not accurate since radial flow conditions were not reached during the flow period. The Pr1 buildup analysis indicated two distinct straight line slopes, one of which may have been reflecting a boundary condition. In response to uncertainty from the typical field analyses, simulations using Glimpse had been made in the field during testing to attempt to bound the data. These indicated a wide range on conductivity from about 1e-11 to 1e-10 m/s.

The shut-in transient responses indicated that the zone had a relatively low conductivity. The flow event, however, indicated higher conductivities.

The GLIMPSE model was used to attempt to bound the interval data. Simulation runs demonstrating the approach is shown in Figures C2.2 and C2.3. Bounding attempts were made with and without borehole history over a relatively wide range of conductivity, storativity and static pressure values. None of the results were satisfactory.

No value of static pressure could be determined from the testing since the zone was too tight. A range of 150 to 350 kPa was used during attempts at bounding.

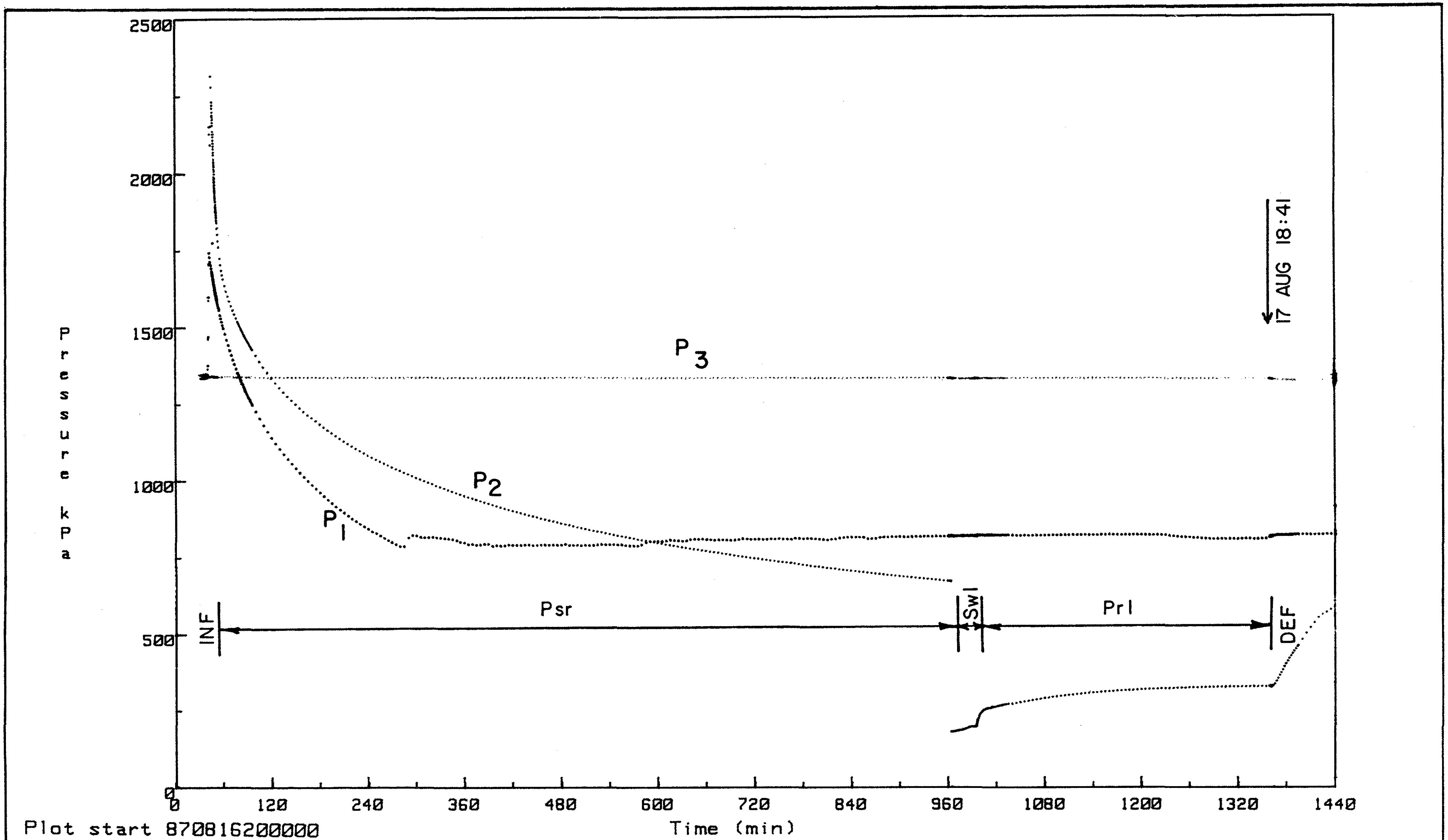
C2.4.2 Results

Borehole history pressures were between 1050 and 1400 kPa during the almost 28 days prior to testing. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing. This combined with the low permeability for the interval meant that no value of static pressure considered representative of interval conditions was determined.

The value at the end of the Psr event was 670 kPa. The value at the end of the Pr1 event was 329 kPa and still increasing. However, this increase, based on the conductivity of the zone could have been in response to the borehole history pressures. A value of between 150 and 350 is possible for the static pressure in this zone given the potential borehole history influence.

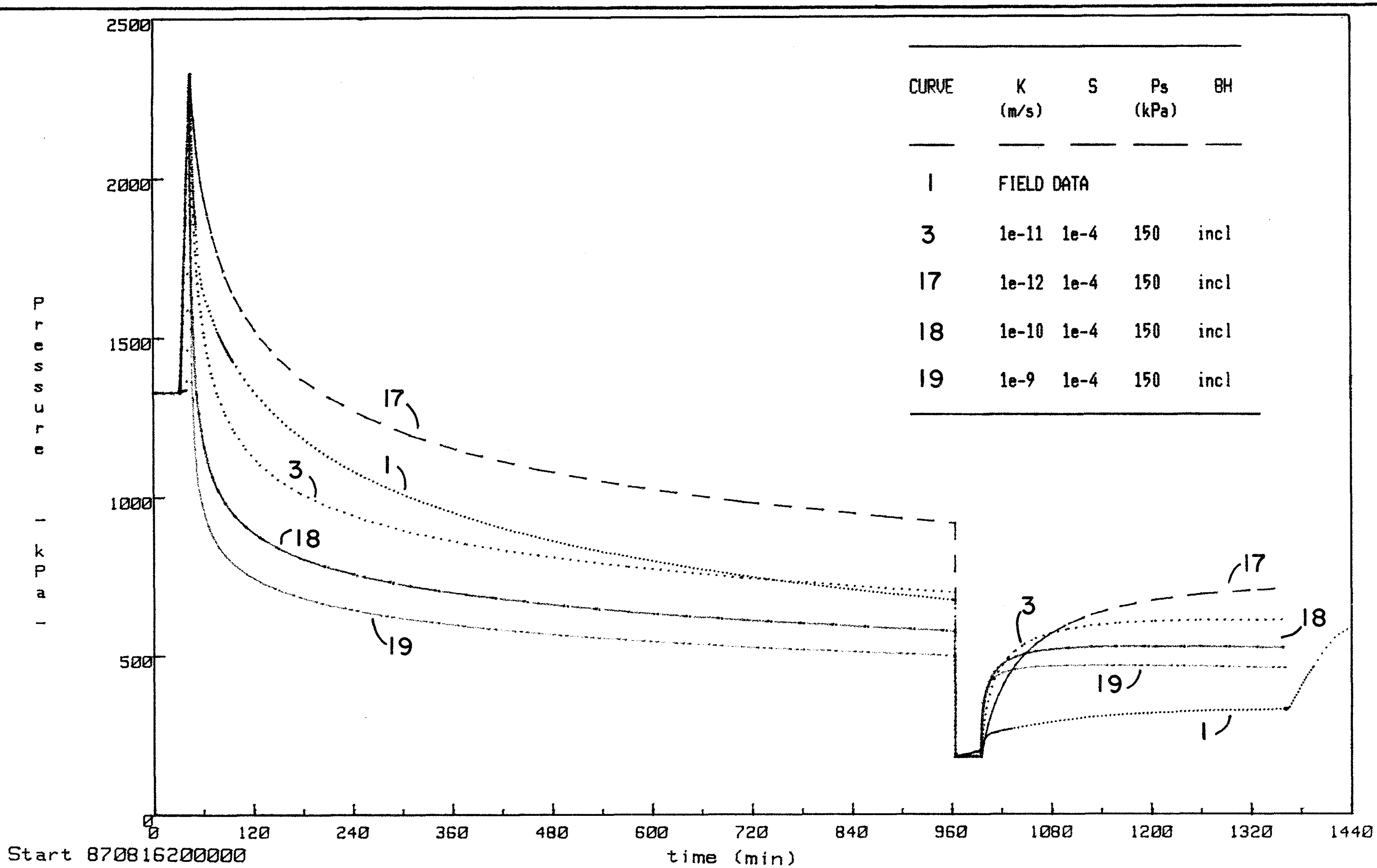
The data was not able to be bounded with a consistent set of hydraulic parameter values for all events. Assigning hydraulic conductivity between 1e-11 m/s and 1e-9 m/s at storativities ranging from 1e-6 to 1e-4 is reasonable based on the diversity of response in the interval and the uncertainty in the static pressure.

Skin effect may have influenced the Psr and other events. The irregular flow during Sw1 could have been caused by plugging. The model conditions used in the analysis may not match those of the zone tested. Any of these factors could account for the inability of the simulations to consistently bound the data.



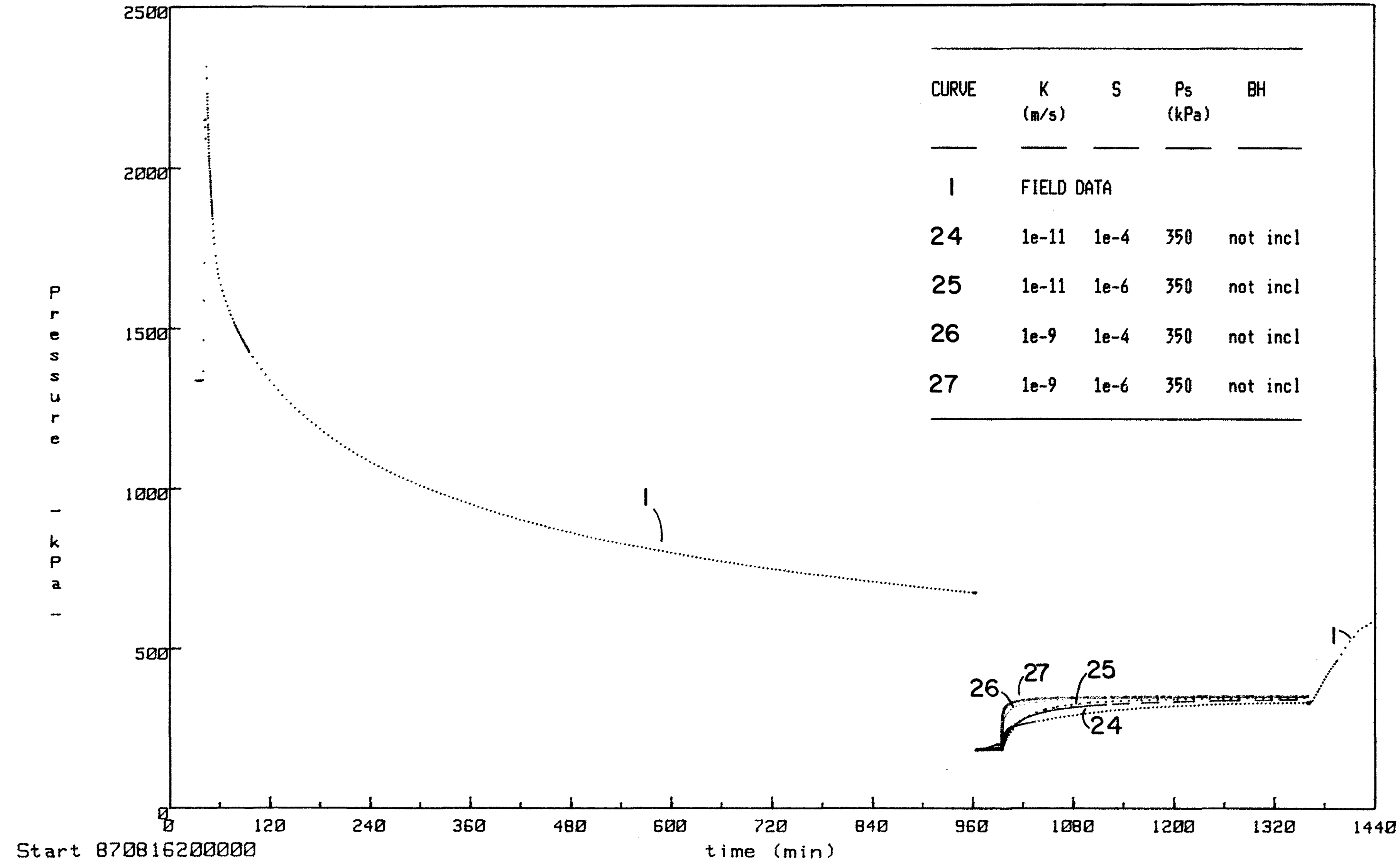
NAGRA / GLAG NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C2.1

PRESSURE SEQUENCE PLOT - SA/137.0D



NAGRA / GLAG NTB:88-03	OBERBAUENSTOCK	DAT.: APR. 88	C2.2

EXAMPLE SIMULATION 1 - SA/137.0D



CURVE	K (m/s)	S	Ps (kPa)	BH
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25	1e-11	1e-6	350	not incl
26	1e-9	1e-4	350	not incl
27	1e-9	1e-6	350	not incl

NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | C2.3

EXAMPLE SIMULATION 2 - SA/137.0D

C3. APPENDIX C3: INTERVAL SA/157.0D

This interval was tested using a double straddle packer assembly with a length of 19.1 m. The upper and lower packer seats were at 147.5 m and 166.6 m, respectively. Testing details are included in NIB 88-04, Section H.

C3.1 HYDROGEOLOGICAL SETTING

The interval consisted of a highly fractured , grey, layered marlstone. An open fracture occurred at 158 m. RQD varied from 50 to 90 percent.

Part of this interval was previously tested as the SA/160.6S zone after fluid losses were noted during drilling. This last test in the borehole was essentially a retest of that interval. The purpose of the testing was first, to document the anomalously low pressure that had been obtained during the SA/160.6S interval, and second, to attempt to detect if there was any boundary observable after injection tests.

The interval caliper log went off the scale at 150 mm at a depth of 153 m.

C3.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to 166m,
2. Run-in, testing 160.6S, and run-out,
3. Drilling to 300.2 m,
4. Geophysical logging and drilling to total depth,
5. Geophysical logging,
6. Run-in, testing 298.0D, 311.0D, run-out,
7. Changing straddle, run-in and test 196.5D1,
8. Run-out, repair equipment and run-in, and,
9. Detailed tests 137.0D and 196.5D2.

These activities took place over almost 28 days prior to testing.

C3.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figures C3.1 and C3.2, included:

1.	Inflation	INF
2.	Shut-in static recovery	Psr
3.	Slug withdrawal 1	Sw1
4.	Pressure recovery 1	Pr1
5.	Slug withdrawal 2	Sw2
6.	Injection 1	INJ1
7.	Pressure recovery 2	Pr2
8.	Injection 2	INJ2
9.	Pressure recovery 3	Pr3
10.	Injection 3	INJ3
11.	Pressure recovery 4	Pr4
12.	Deflation	DEF

C3.3.1 <u>Interval Response</u>

The tubing was run in dry and the FAV was kept closed during inflation. No compliance period was possible.

Testing began with a 620 minute Psr event during which time the pressure decreased from 3220 kPa, which occurred as a result of packer squeeze during inflation, to a final value of 800 kPa. The Psr event had been prolonged to see if the P2 pressure would fall below the P1 bottomhole pressure.

The FAV was opened and the zone subjected to an initial pressure of 150 kPa at the start of Sw1. An under-pressure was used to see if fluid would flow up into the tubing. The flowing pressure increased in two distinct steps. The first was a 20 kPa increase the first 3 minutes. The second was a slower continual rise of 8 kPa during the last 30 minutes. The final flowing pressure was 178 kPa. A possible explanation for the difference was that a gas forced the liquid level up into the tubing at the start of the flow. In this situation, the second flow rate would represent the formation yield.

Pr1 was monitored for 486 minutes during which time the pressure increased to 386 kPa, a value considerably lower than what had been expected based on the results of the Psr response.

The FAV was opened again and the zone subjected to an initial pressure of 183 kPa at the start of Sw2. The second slug test was done to clarify which flow response from the fist test was correct. The flowing pressure increased consistently by 10 kPa during the 37 minute event. The final flowing pressure was 193 kPa.

The interval preliminary testing was terminated at this point in preparation for the injection testing.

A series of three relatively constant pressure injection and shut-in falloff recovery events were conducted. INJ1 lasted 24.5 hours at an average pressure of about 60 bars. The Pr2 falloff lasted 21.5 hours and the pressure decreased to 373 kPa.

INJ2 lasted about 25 hours at an average pressure of about 67 bars. Communication between the interval and the bottomhole zone developed through the rock during this event. The Pr3 falloff lasted about 22 hours and the pressure decreased to 860 kPa.

INJ3 lasted 7 hours at an average pressure of about 78 bars. The Pr2 falloff lasted about 19 hours and the pressure decreased to 957 kPa.

Once communication developed, it appeared that the P1 and P2 pressures were composite values.

C3.3.2 Annulus Response

The pressure decreased by about 12 kPa during the preliminary testing. The response during the injection testing was affected by water overflowing into the annulus.

C3.3.3 Bottomhole Response

The P1 line to surface was disconnected downhole so there was no line hydraulics affecting the bottomhole response. The P1 pressure increased by about 400 kPa during inflation in response to packer squeeze. It decreased thereafter and stabilized at between about 985 and 1000 kPa during the preliminary testing. This corresponded to a hydraulic head elevation about equal to Lake Uri.

Pressures began to noticeably increase about 1 hour into the first injection period. After an initial increase, however, they appeared to stabilize. Pressures began their confirming upward trend about 12 hours into the INJ2 event and reached a maximum of about 2500 kPa when INJ2 was terminated. The P1 and P2 pressures fell in a similar manner during

Pr3. Towards the end of Pr3, however, the P1 pressure had increased and was about 170 kPa higher than P2. P1 pressures began increasing as soon ads the INJ3 event began and increased to 1123 kPa. They continued increasing after the injection stopped and then began to decrease. The final P1 and P2 end pressures were similar ar 982 and 957 kPa, respectively.

C3.3.4 Packer Pressure Response

The packer pressure was controlled at surface with a pressure regulator and nitrogen gas source. The pressure decreased by about 60 kPa during the preliminary testing. During the injection testing, the valve to the nitrogen tank was mistakenly turned off and the packer pressure decreased. This was corrected with no apparent interval-related pressure response.

Packer pressures increased during the injection periods in response to the increased pressures being exerted downhole. Pressure in the packer inflation line was intentionally bled off at one point to limit the inflation line pressure.

C3.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 19.0°C and 19.7°C during the preliminary events. Once injection testing began, individual thermistors had fluctuations as high as 2°C. The lake water used for the injection accounts for this variation. The surface probe temperature varied from 21.9°C to 23.3°C.

C3.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures opposite the interval during drilling and the following borehole history activities may have influenced the formation response during testing.

C3.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The response of the Sw1 event was too irregular, and the Sw2 recovery too small to analyze accurately with type curves. No horner-type analysis of Pr1 was attempted since radial flow conditions were not likely reached during the flow period. The final three falloff recovery events were analyzed and indicated conductivity values from about 4e-9 to 2e-8 m/s.

The GLIMPSE model was used to attempt to bound the interval data. Simulation runs demonstrating the approach is shown in Figures C3.3 and C3.4. Results from attempts at bounding the preliminary testing data indicated conductivity values from one to two orders of magnitude lower than the results from the injection testing. Bounding attempts for the final injection activities were made with borehole history over a relatively narrow range of conductivity values with a reasonable range of storativity and static pressures ranging from 250 to 400 kPa.

No value of static pressure could be determined from the testing. A range of 250 to 400 kPa was used during attempts at bounding.

C3.4.2 Results

Borehole history pressures generally were about 1500 kPa during the almost 28 days prior to testing. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing. This combined with the irregular response in the interval meant that no value of static pressure considered representative of interval conditions was determined.

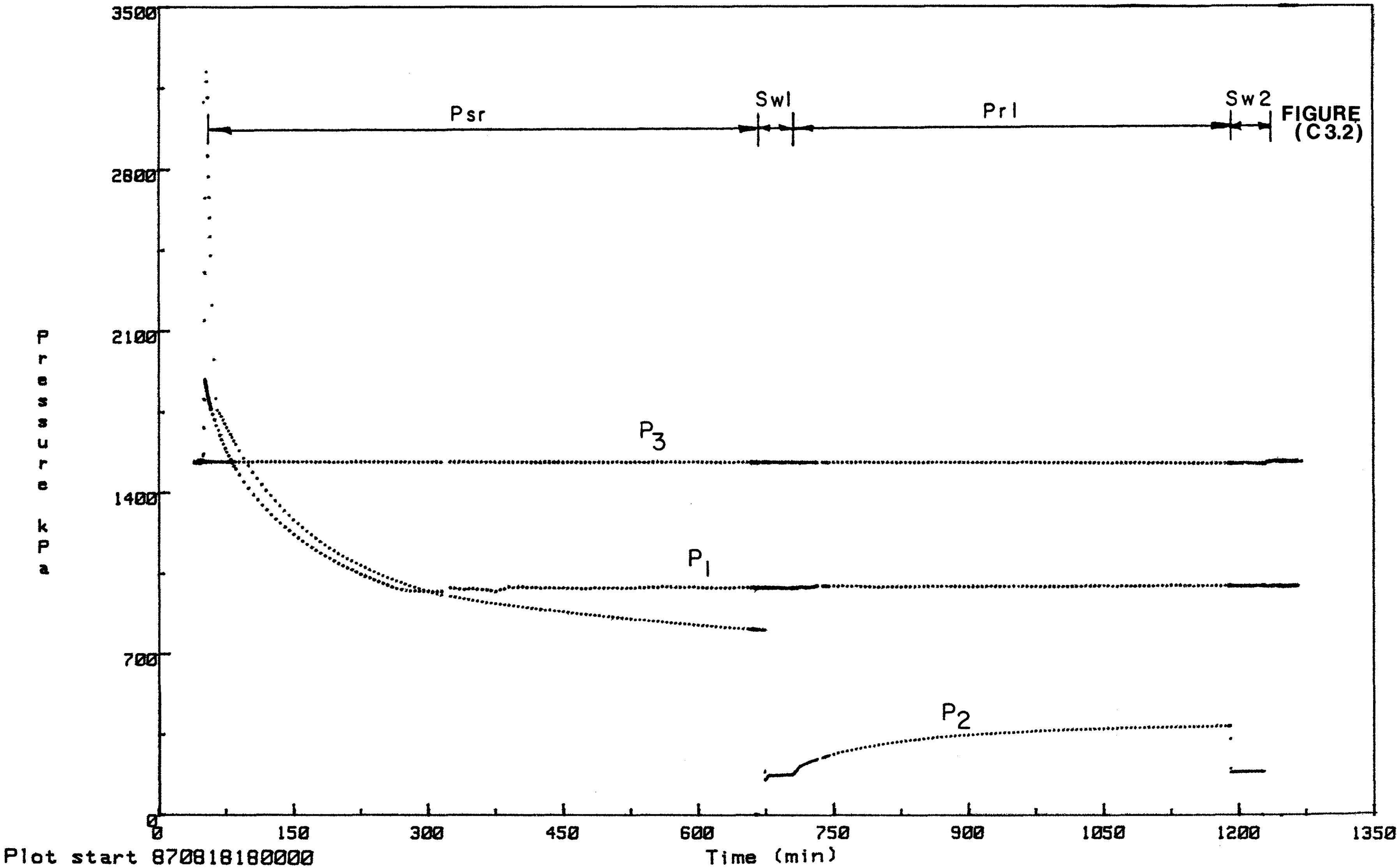
The value at the end of the Psr event was 800 kPa. The value at the end of the Pr1 event was 3869 kPa and increasing slowly. However, this increase, based on the conductivity of the zone could have been in response to the borehole history pressures. A value of between 250 and 400 is possible for the static pressure in this zone given the potential borehole history influence. This range of static pressures would have hydraulic head elevations of 363 to 378 m (asl), respectively, compared to the Lake Uri level of 433 m.

The data was not able to be bounded with a consistent set of hydraulic parameter values for all events.

Skin effect may have influenced the preliminary testing. The irregular flow during Sw1 could have been caused by a gas in the system. The model conditions used in the analysis may not match those of the zone tested. Any of these factors could account for the inability of the simulations to consistently bound all the event data.

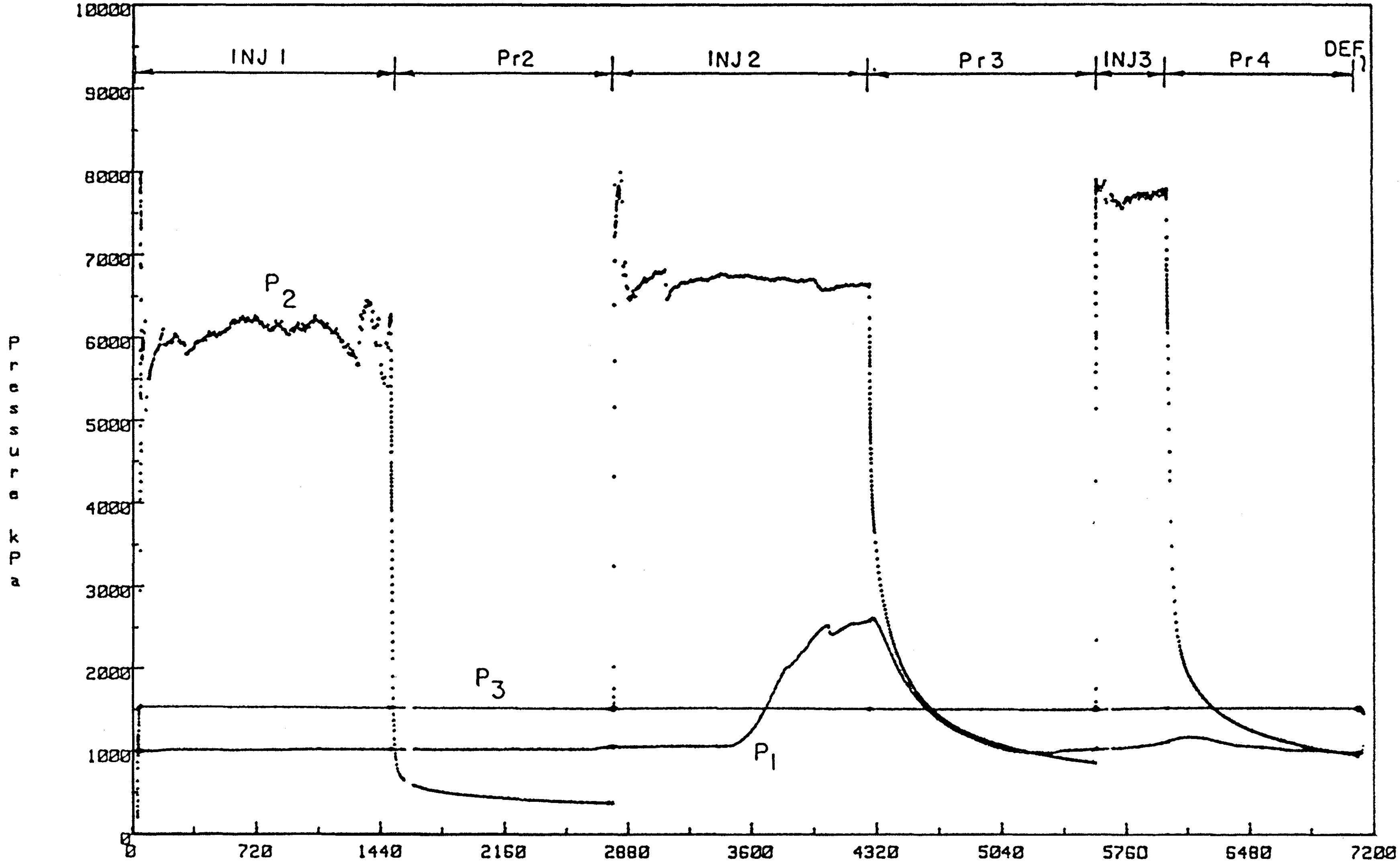
Assuming that a skin effect limited the response during the preliminary testing, and that the interval was characterized during the injection and falloff events, then assigning hydraulic conductivity between 1e-9 m/s and 1e-8 m/s at storativities ranging from 1e-7 to 1e-3 is reasonable based on the diversity of response in the interval and the uncertainty in the static pressure.

No analysis was made concerning potential boundary conditions or reservoir limits has been done at this time. Additional assumptions regarding the shape and nature of pathway that developed between the straddle and bottomhole intervals would be need for further analysis.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C3.1

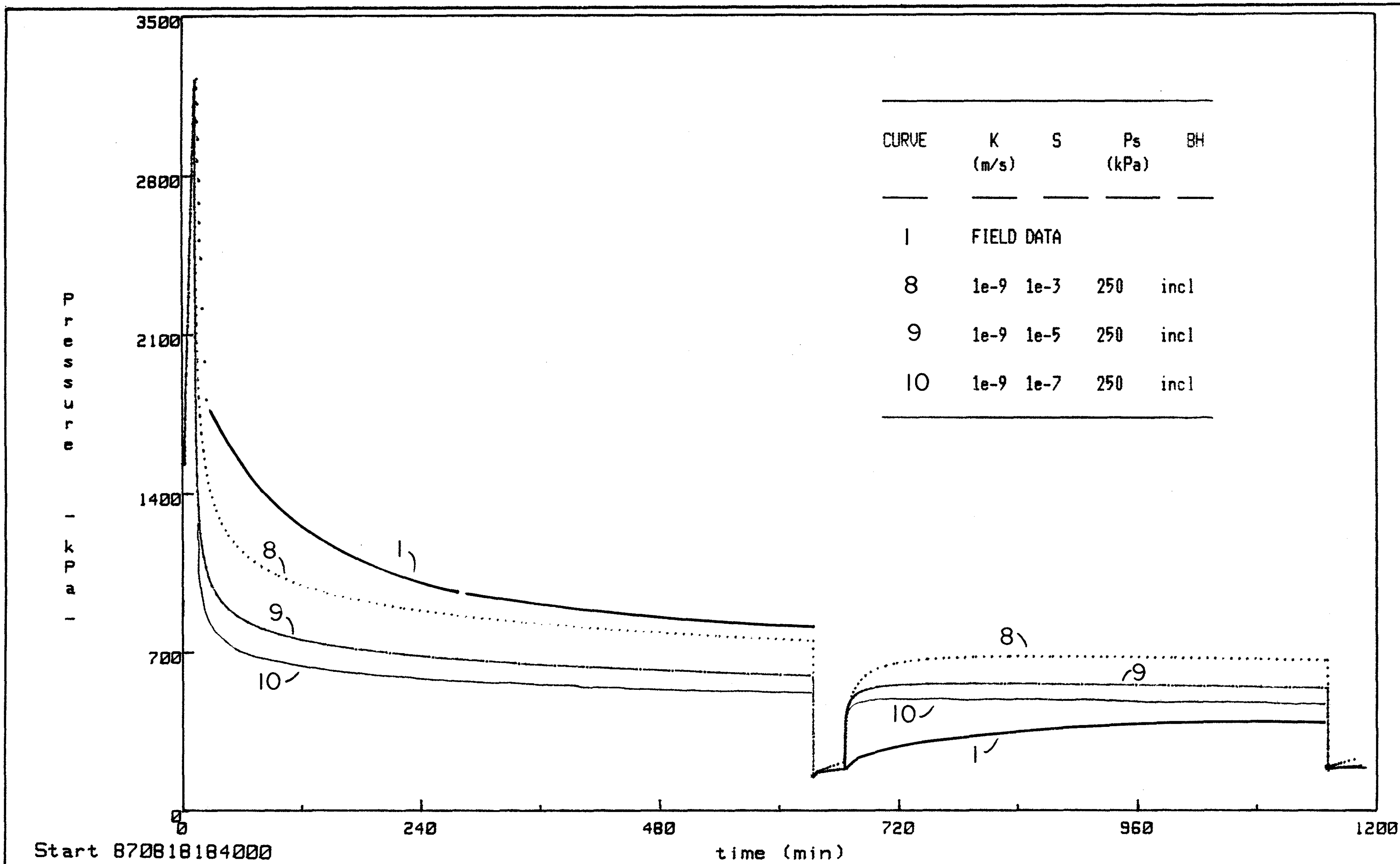
PRESSURE SEQUENCE PLOT 1 - SA/157.0D



Plot start 870819140000

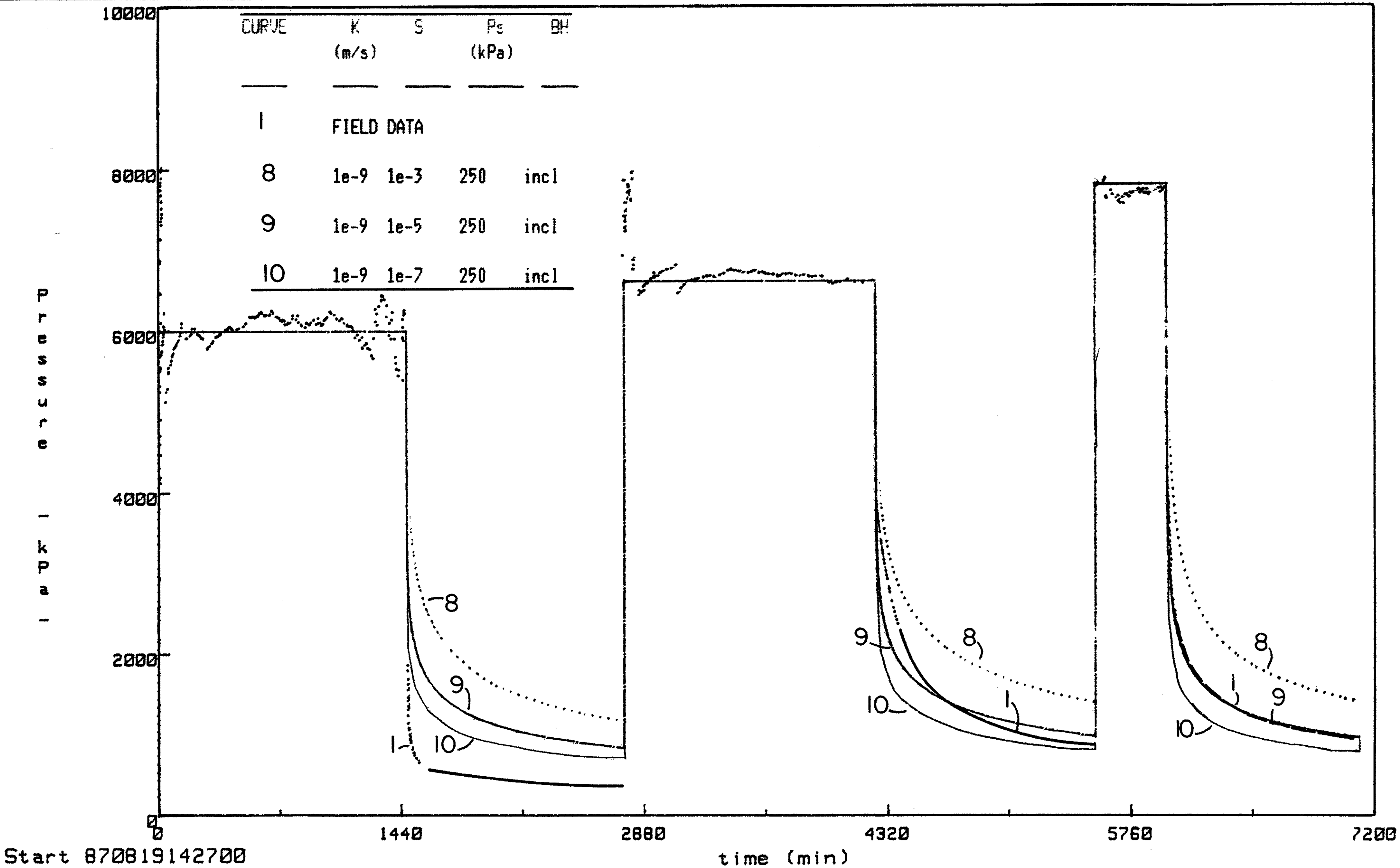
NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C3.2

PRESSURE SEQUENCE PLOT 2 - SA/157.0D



NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | C3.3

EXAMPLE SIMULATION 1 - SA/157.0D



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C3.4

EXAMPLE SIMULATION 2 - SA/157.0D

C4. APPENDIX C4: INTERVAL SA/160.6S

This interval was tested using a single packer assembly with an open borehole length of 19.1 m. The upper packer seat and total drilled depth were at 156.0 m and 165.8 m, respectively. Testing details are included in NIB 88-04, Section B.

C4.1 HYDROGEOLOGICAL SETTING

The interval consisted of a highly fractured , grey, layered marlstone. An open fracture occurred at 158 m. RQD varied from 50 to 90 percent.

Drilling was interrupted to test this interval. About 1500 liters had been lost during drilling. The caliper log showed 3 enlarged zones with diameters of 108 mm at 156 and 158 m and to 127 mm at 163 m.

C4.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to 166m, and,
2. Run-in of the testing equipment.

These activities took place over about 22 hours prior to testing.

C4.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure C4.1, included:

1. Inflation	INF
2. Compliance	COM
3. Shut-in static recovery	Psr
4. Slug injection 1	Si1
5. Pressure recovery 1	Pr1
6. Slug withdrawal 1	Sw1
7. Slug withdrawal 2	Sw2
8. Pressure recovery 2	Pr2
9. Slug injection 1	Si1
10. Pressure recovery 2	Pr2
11. Flow injection	Flow
12. Deflation	DEF

NAGRA conducted an open hole injection test at the end of the testing after the downhole testing equipment had been removed from the borehole. Traced fluid was injected at up to 65 Bars pressure. NAGRA has additional details inhouse regarding this activity.

C4.3.1 Interval Response

The testing began with a 76 minute compliance period during which time the fluid level dropped about 11 m in the tubing to a final pressure of 353 kPa. The Psr event lasted 255 minutes and the pressure decreased and stabilized at about 289 kPa.

The first diagnostic test was a slug rather than a pulse test because of the higher expected permeability. The tubing was filled and the FAV was opened. Si1 lasted 29 minutes during which time the net decrease was 36 kPa. The abrupt pressure change that occurred partway through the test was caused by submerging the Bennett pump prematurely. The FAV was then closed to monitor the Pr1 falloff. Pressures decreased by 313 kPa to a final value of 287 kPa during the 169 minute event.

The fluid level was lowered in the tubing using the Bennett pump. The FAV was opened and the zone subjected to an initial pressure of 182 kPa at the start of Sw1. An underpressure was used to see if fluid would flow up into the tubing. The pressure increased by 73 kPa in 99 minutes. The Bennett pump was raised mistakenly thinking the FAV was closed. This lowered the fluid level in the tubing to start the Sw2 event. This lasted 18 minutes during which time the pressure increased in a similar manner. The FAV was then closed in preparation for filling the tubing and conducting the next injection test. However, there there was little change in the recovery rate after shut in. The pressure increased by 22 kPa in 43 minutes to a final pressure of 263 kPa.

The FAV was opened after the tubing had been filled. The Si2 event lasted 100 minutes during which time the pressure fell by 517 kPa to a final flowing pressure of 758 kPa. The FAV was closed for Pr3 and the pressure dropped rapidly and stabilized at about 305 kPa after 93 minutes.

The Flow period event was conducted using the HVT connected to the wellhead. Flow measurements were made by measuring the fluid level drop in the HVT. This event lasted about 4 hours. Average flow rates were about 1.5 litres/min. Pressures decreased from 1328 to 1179 kPa.

C4.3.2 Annulus Response

The pressure increase that occurred during the COM event was caused by the annulus being filled. Thereafter, the pressure decayed by less than 10 kPa.

C4.3.3 Bottomhole Response

This was a single packer test. Accordingly, the P1 port monitored the zone below the only packer.

C4.3.4 Packer Pressure Response

The packer pressure was controlled at surface with a pressure regulator and nitrogen gas source. The pressure decreased by about 50 kPa during testing.

C4.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 19.4°C and 20.6°C during testing. The surface probe temperature varied from 21.3°C to 22.1°C.

C4.4 INTERPRETATION AND RESULTS

This interval was selected for testing due to documented fluid losses both during drilling and during preparations and run-in of the equipment.

The drilling fluid levels are relatively well documented. The pressures opposite the interval afterwards are less precise. However, the interval's anomalously low pressure determined during testing means that overpressures as large as 1300 kPa existed prior to testing.

C4.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The straight-line analysis of the Psr period was possible because of the documented flow conditions that occurred during compliance. This and the analysis of the Pr1 event following Si1 indicated hydraulic conductivities on the order of 1e-8 m/s.

Type-curve matches of the Sw1 and Si2 slug test data indicated conductivity of about 4e-8 m/s. The final Pr2 event analysis indicated about the same result. No analysis was made of the flow period activity.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Figure C4.2.

A static pressure value of about 280 to 290 kPa was expected based on the response in the interval. This pressure was a complete surprise during the testing program. A range of 250 to 290 kPa was used during attempts at bounding.

Attempts at bounding were not successful when including borehole history. Final simulations did not include these pressures.

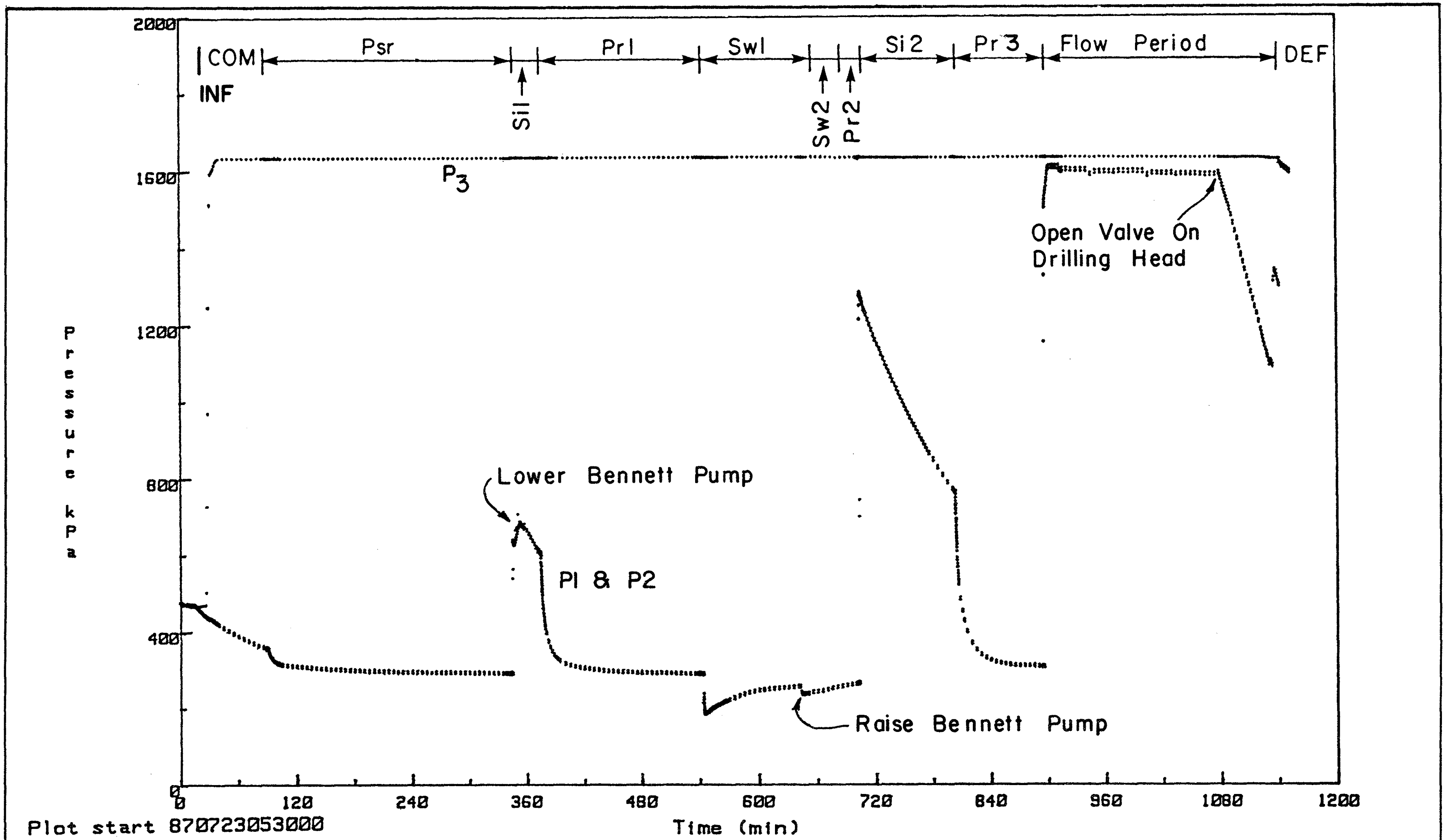
C4.4.2 Results

Borehole history pressures generally were about 1600 kPa during the 23 hours prior to testing. It was expected that these pressures would influence the pressure response.

The pressure value at the end of the Psr event was 289 kPa. The values at the end of the Pr1, Pr2 and Pr3 events were 287, 263 and 305 kPa, respectively. The bounding analysis, excluding borehole history suggested values of about 250 to 270 kPa would be reasonable. This range of static pressures would have hydraulic head elevations of 355 to 357 m (asl), respectively, compared to the drilling gallery elevation and Lake Uri level of 494 and 433 m, respectively.

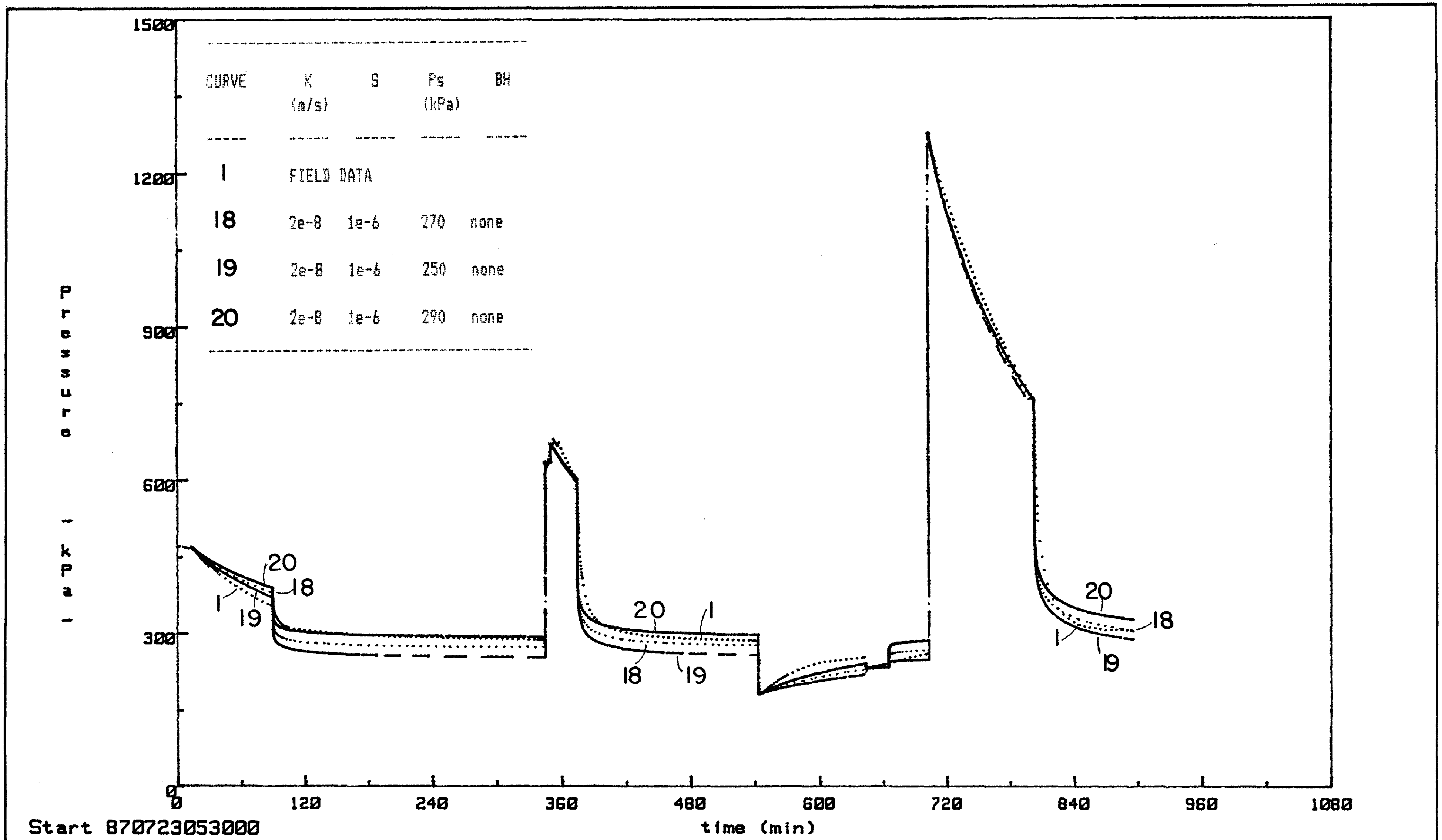
The data was bounded with a hydraulic conductivity of about 1e-8 m/s for a storativity range from 1e-6 to 1e-3, excluding borehole history. Model conditions used in the analysis may not match those of the zone tested. A skin, near wellbore constant pressure boundary or an even lower in-situ pressure prior to testing are mechanisms that could explain why the simulations did not bound the data well when borehole history was not included.

The anomalously low pressure documented for the interval is still being evaluated.



NAGRA / GLAG NTB:88-03	OBERBAUENSTOCK	DAT.: APR. 88	C4.1

PRESSURE SEQUENCE PLOT - SA/160.6S



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C4.2

EXAMPLE SIMULATION - SA/160.6S

C5. APPENDIX C5: INTERVAL SA/196.5D1

This interval was tested using a double straddle packer assembly with a length of 19.1 m. The upper and lower packer seats were at 187.0 m and 206.1 m, respectively. Testing details are included in NIB 88-04, Section E.

C5.1 HYDROGEOLOGICAL SETTING

The interval consisted of layered marlstone with open fractures at 197, 199, and 201 m. Fracture density was between 5 and 10 per metre. RQD varied from 40 to 90 percent.

This was the third detailed interval tested after completion of drilling. The purpose of the testing was to determine the static pressure in an interval to be compared to the low pressure documented in the 160.6S interval.

C5.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling to 300 m,
2. Geophysical logging and drilling to total depth,
3. Geophysical logging,
4. Run-in, testing 298.0D, 311.0D, run-out, and,
5. Changing straddle, run-in.

These activities took place over about 17 days prior to testing.

C5.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure C5.1, included:

1. Inflation	INF
2. Compliance	COM
3. Shut-in static recovery	Psr
4. Deflation	DEF

The FAV failed to open at the end of about 6 hours. Testing was continued to attempt to obtain additional data about the pressure response.

C5.3.1 Interval Response

Testing began with a 67 minute compliance period during which time the fluid level dropped by about 0.4 m in the tubing to an end pressure value of 1925 kPa. The FAV was closed and the pressure dropped in an erratic manner for about 18 hours. At that point the pressure was about 750 kPa and a change in the rate of pressure decreased began (Figure C5.1, Point A). Thereafter and for the remaining event time of about 44 hours, it decreased at an increasingly slower rate to a final shut-in pressure of 613 kPa.

The FAV failure resulted in a longer monitoring period than had been planned, but was justified to gain more data about the borehole static pressure distribution.

The interval testing was terminated and the equipment was removed from the borehole to repair the FAV cable.

C5.3.2 Annulus Response

The pressure decreased by about 80 kPa during testing.

C5.3.3 Bottomhole Response

The P1 line to surface was disconnected downhole so there was no line hydraulics affecting the bottomhole response. The P1 pressure increased by 120 kPa during inflation in response to packer squeeze. It decreased over the next five hours to 1390 kPa. At that point, it increased (Figure C5.1, Point B to C) and then gradually decreased and increased over the duration of testing. The final pressure was 1416 kPa.

C5.3.4 Packer Pressure Response

The packer pressure was controlled at surface with a pressure regulator and nitrogen gas source. The pressure decreased by about 165 kPa during the 64 hours of testing.

C5.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 19.9°C and 21.0°C. The surface probe temperature varied from 21.8°C to 21.9°C.

C5.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures opposite the interval during drilling and the following borehole history activities likely influenced the formation response during testing.

C5.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

No diagnostic tests were able to be performed because the FAV did not open. Therefore, there is no data to evaluate the hydraulic conductivity of the interval.

However, the pressure response was evaluated to attempt to define an upper limit for a static pressure value. Log-log plots of the Psr data were made to extrapolate the anticipated end pressures. In addition, horner-type plots were made of the Psr data using, for the length of the inflow time, first, the entire borehole history period prior to Psr, and second, just the COM time of 67 minutes.

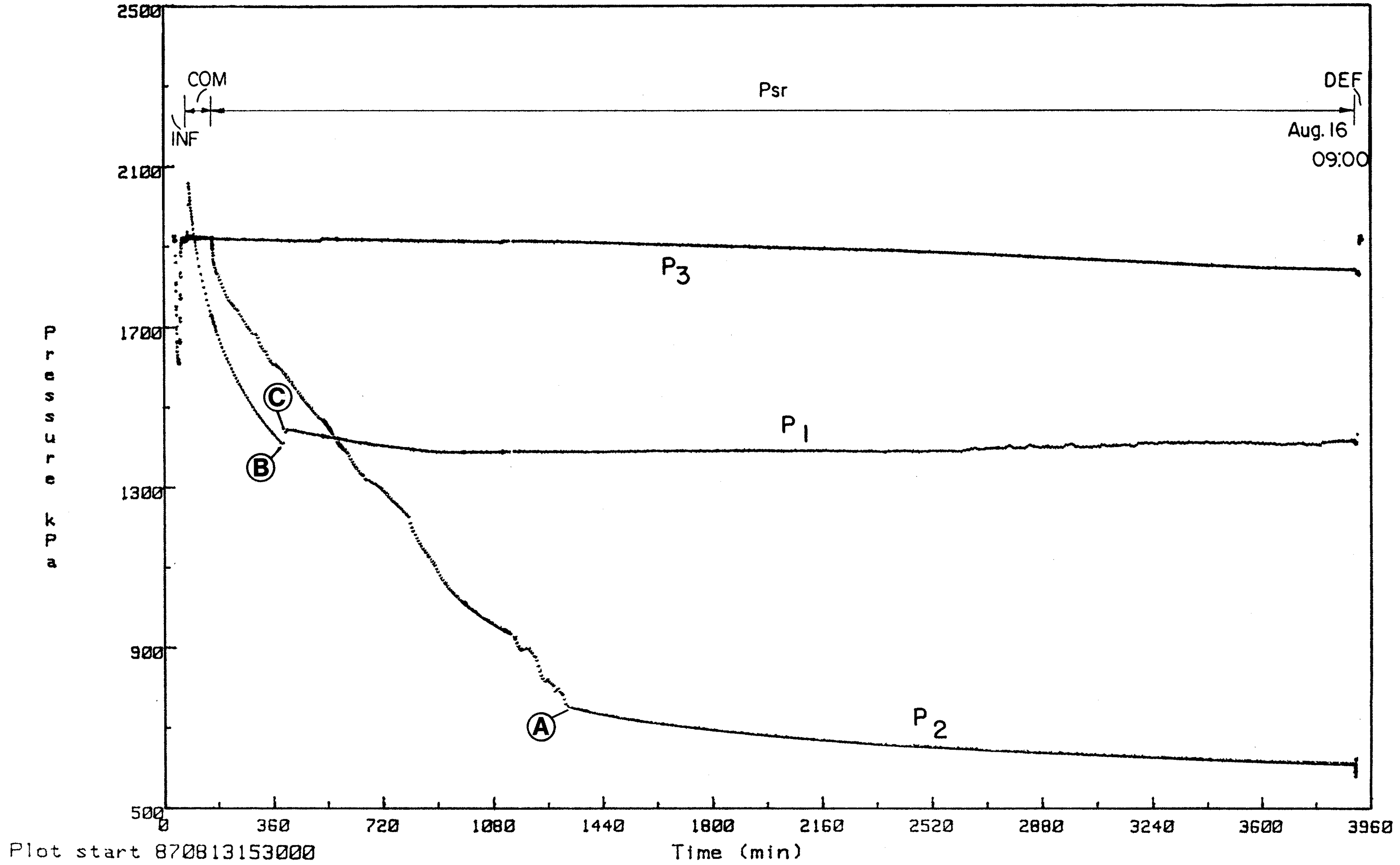
C5.4.2 Results

Borehole history pressures were about 1940 kPa during about 17 days prior to testing. Pressures decreased to about 1750 kPa opposite the interval during the annulus level decrease when SA/311.0D was being tested. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing.

The value at the end of the Psr event was 613 kPa and still decreasing at about 2 kPa/hour. The extrapolated end pressure values based on the log-log and semi-log plots of the Psr data indicated ranged between 440 and 540 kPa. Hydraulic head elevations corresponding to these values would be 344 to 354 m (asl), respectively compared to the Lake Uri level and SA/160.6S hydraulic head elevations of 433 and 356 m, respectively.

No attempts were made to bounded the test data since no active transient testing was done and a second testing in the interval was available for this purpose.

Skin effect or initially free gas in the vicinity of the test section may have influenced the Psr events. These are some of the mechanisms that could account for the erratic pressure decline response in the interval.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C5.1

PRESSURE SEQUENCE PLOT - SA/196.5D1

C6. APPENDIX C6: INTERVAL SA/196.5D2

This interval was tested using a double straddle packer assembly with a length of 19.1 m. The upper and lower packer seats were at 187.0 m and 206.1 m, respectively. Testing details are included in NIB 88-04, Section G.

C6.1 HYDROGEOLOGICAL SETTING

The interval consisted of layered marlstone with open fractures at 197, 199, and 201 m. Fracture density was between 5 and 10 per metre. RQD varied from 40 to 90 percent.

This was the second testing done of this interval and the fifth detailed interval tested after completion of drilling. The purpose of the testing was to determine the hydraulic characteristics of the interval. The previous testing had established that the static pressure in an interval was likely in the range of 440 to 540 kPa.

C6.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to 166m,
2. Run-in, testing 160.6S, and run-out,
3. Drilling to 300.2 m,
4. Geophysical logging and drilling to total depth,
5. Geophysical logging,
6. Run-in, testing 298.0D, 311.0D, run-out,
7. Changing straddle, run-in and test 196.5D1,
8. Run-out, repair the equipment and run-in, and,
9. Testing 137.0D.

These activities took place over almost 22 days prior to testing.

C6.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure C6.1, included:

1. Inflation	INF
2. Shut-in static recovery	Psr
3. Slug withdrawal1	Sw1
4. Pressure recovery 1	Pr1
5. Pulse injection 1	Pi1

6. Pulse injection 2 Pi2
7. Deflation DEF

C6.3.1 Interval Response

The tubing was run in dry and the FAV was kept closed during inflation. No compliance period was possible.

Testing began with a short 27 minute Psr event because the maximum possible pressure had been relatively well established during the previous interval testing. The interval pressure increased first to about 2350 kPa as a result of packer squeeze during inflation, and then decreased to a final value of 1766 kPa. This short response could have been influenced by packer compliance.

The FAV was opened and the zone subjected to an initial pressure of 414 kPa at the start of Sw1. An under-pressure was used to see if fluid would flow up into the tubing. The flowing pressure increased by 36 kPa during the 56 minute event to a final value of 450 kPa. The Pr1 recovery was monitored for 815 minutes during which time the pressure increased to 620 kPa.

Pi1 was done with an initial pressure of 718 kPa. It continued for 44 minutes and decayed to a final value of about 640 kPa. Pi2 was done with an initial pressure of 1570 kPa. It continued for 41 minutes and decayed to a final value of 765 kPa when the packers were deflated.

C6.3.2 Annulus Response

The pressure had decreased by about 15 kPa during the SA/196.5D1 testing. This time, there was an increase of about 5 kpa.

C6.3.3 Bottomhole Response

The P1 line to surface was disconnected downhole so there was no line hydraulics affecting the bottomhole response. The P1 pressure increased by about 300 kPa during inflation in response to packer squeeze. It decreased thereafter and stabilized rather abruptly at about 1400 kPa.

C6.3.4 Packer Pressure Response

The packer pressure was controlled at surface with a pressure regulator and nitrogen gas source. The pressure decreased by about 80 kPa during the 15 hours of testing.

C6.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 19.9°C and 20.7°C. The surface probe temperature varied from 21.8 °C to 21.9°C.

C6.4 INTERPRETATION AND RESULTS

The drilling fluid levels are relatively well documented. The pressures opposite the interval during drilling and the following borehole history activities likely influenced the formation response during testing.

C6.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The response of the Sw1 event was too small to evaluate accurately with type curves. The horner-type analysis of Pr1 was not accurate since infinite acting radial flow conditions were not reached during the flow period. The two pulse test type-curve matches were not good with the data. The first few minutes of data responded more rapidly than did the later data. The early time match however, indicated a conductivity of about 1e-10 m/s, compared to the 4e-10 m/s from the Pr1 straight line approximation.

The GLIMPSE model was used to attempt to bound the interval data. A simulation runs demonstrating the approach is shown in Figure C6.2. Bounding attempts were made including borehole history over a relatively wide range of conductivity and storativity with static pressure values between 440 and 550 kPa. None of the results were satisfactory.

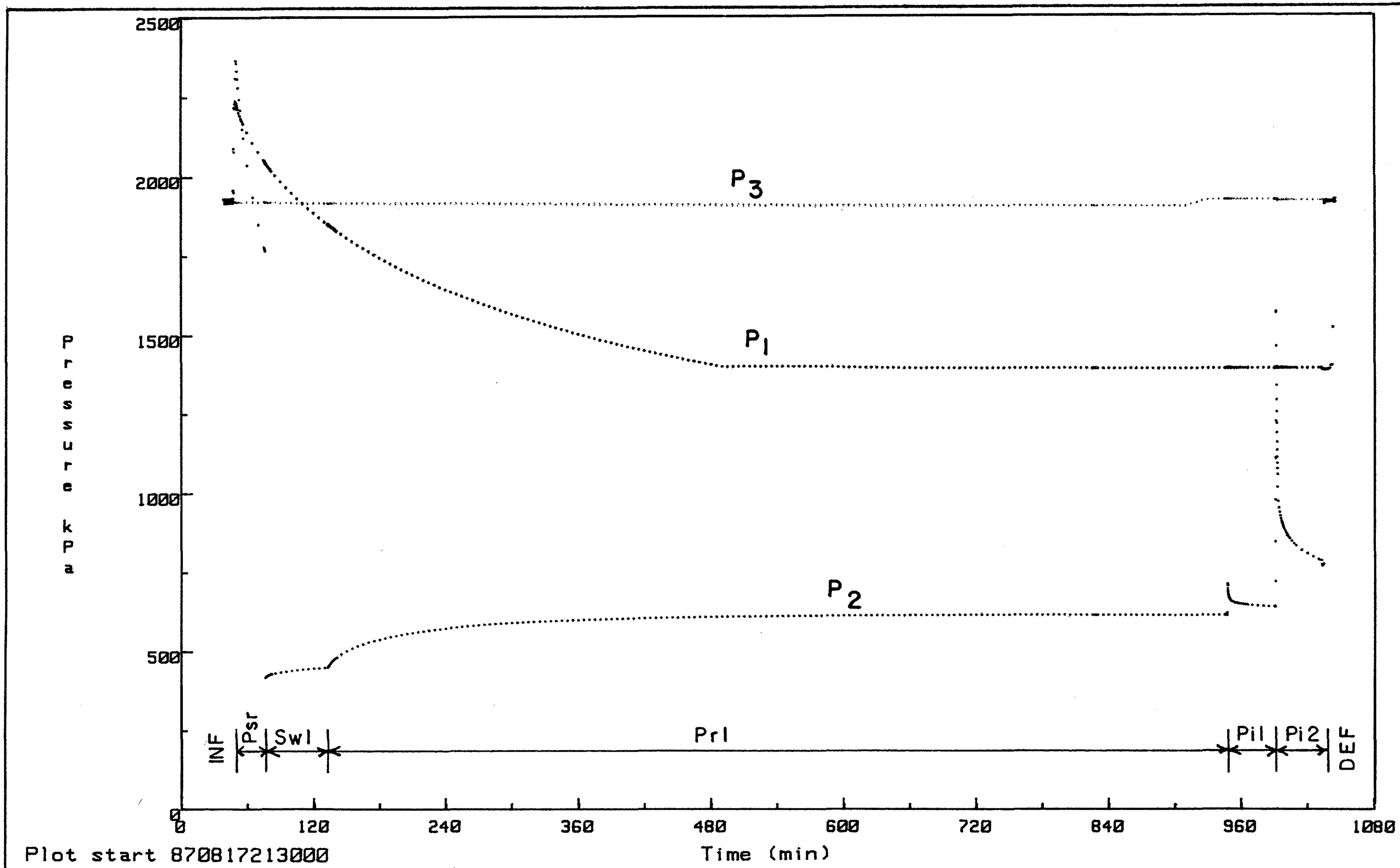
C6.4.2 Results

Borehole history pressures were between 600 and 2300 kPa during the almost 22 days prior to testing. The drilling and other open borehole activities prior to testing affected the pressures in the vicinity of the borehole during testing.

Pressures for the interval had been estimated from the earlier testing. The value at the end of the Pr1 event was 620 kPa and still increasing. However, this increase, based on the conductivity of the zone could have been in response to the borehole history pressures. A value of between 450 and 550 is still suggested as possible for the static pressure in this zone given the potential borehole history influence.

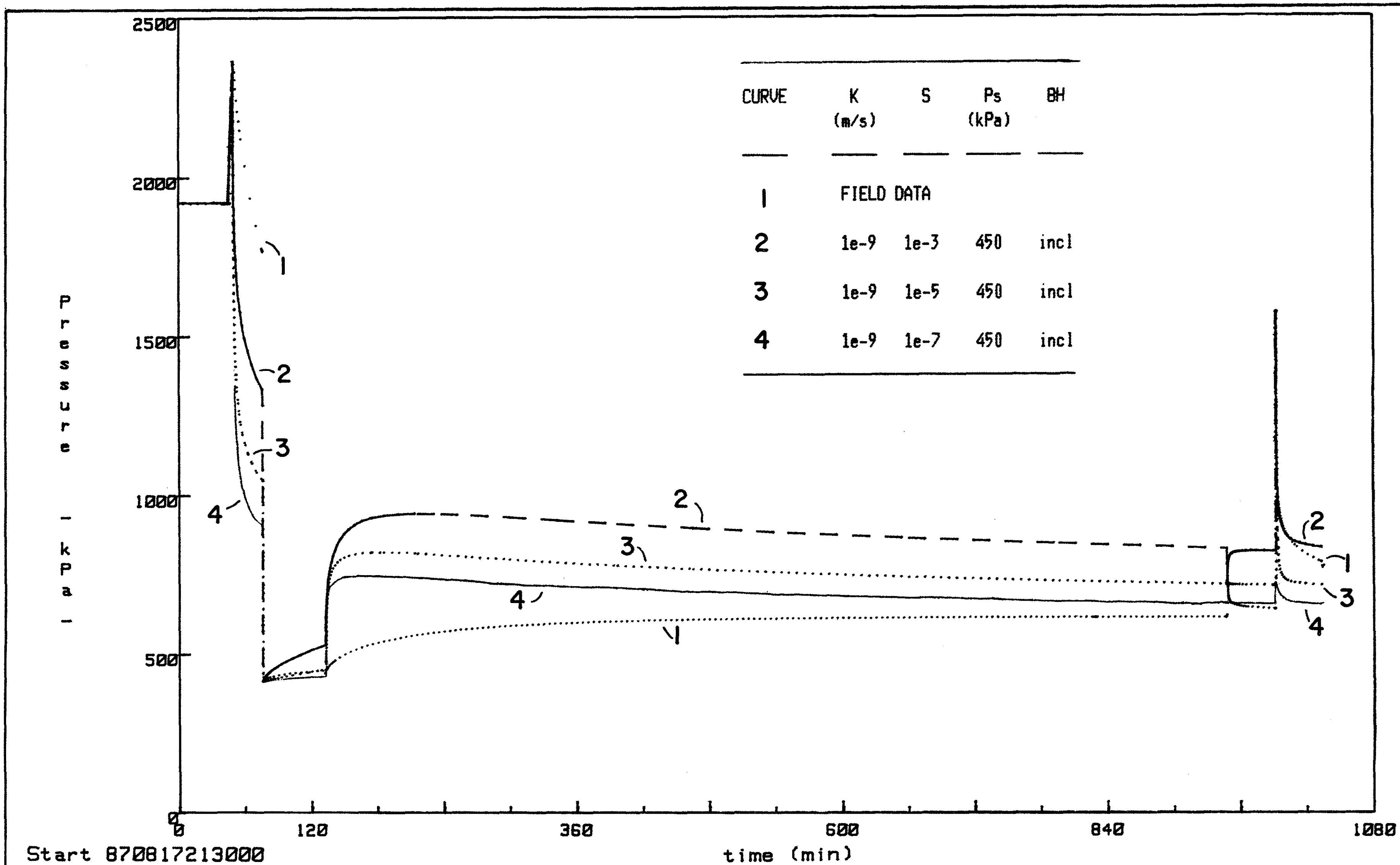
The data was not able to be bounded with a consistent set of hydraulic parameter values for all events including all the borehole history pressures. The responses after Sw1 did respond in a relatively consistent manner, but the influence of borehole history is not as apparent as predicted. Assigning hydraulic conductivity between 5e-11 m/s and 5e-10 m/s at storativities ranging from 1e-7 to 1e-3 is reasonable based on the consistency of response in the interval and the uncertainty in the static pressure.

Skin effect may have reduced the influence of the borehole history pressures on the interval. Fluid losses generally decreased with time in the open borehole suggesting that plugging was taking place. This could also limit the extent of the borehole history pressures. Packer squeeze continuing during Psr likely affected that event's data. The model conditions used in the analysis may not match those of the zone tested. Any of these factors could account for the inability of the simulations to consistently bound the data.



NAGRA / GLAG NTB: 88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | C6.1

PRESSURE SEQUENCE PLOT - SA/196.5D2



NAGRA / GLAG NTB:88-03 | OBERBAUENSTOCK | DAT.: APR. 88 | C6.2

EXAMPLE SIMULATION - SA/196.5D2

GARTNER LEE- OBERBAUENSTOCK: QUICK LOOK REPORT

DATE: Aug/18/87 BY: LD INTERVAL: OBS3/1965D-2

GEOLOGY: Gray to light gray marlstone with calcite infillings. Fracture concentration ~10 per meter at top drops to ~4 at bottom.

GEOPHYSICS: Single Gamma cycles between 35 and 55 cps. Neutron Porosity between ~12 and 15% with a 18% spike at 194m. Caliper max: 108 at 192m

DRILLING: RQD: 50-90%.

TOP: 187.00 m
BTTM: 206.08 m
P2: 184.54 m
ANN LVL: 1m a RP
ANN FLW: ~∅
STRT PP: 6020
END PP: 5940
PCKR dP: 80kPa

BH: 1 drilling 2 test-311 3 test 298 4 test 1965-1 5 test 137 6

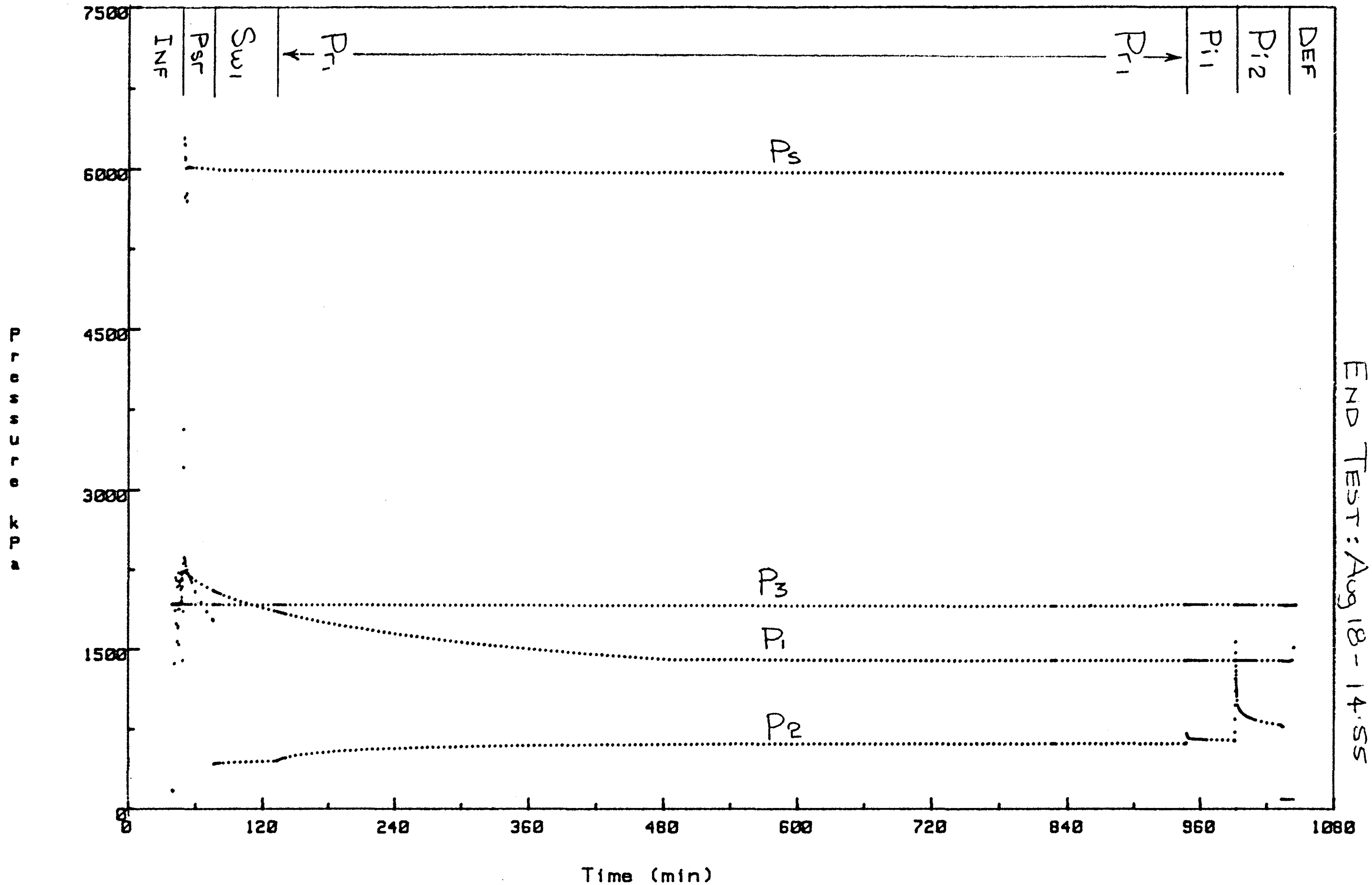
RESULTS: EVENT NAME	INF	Psr (*)	Swi (1)	Pri	Pi1 (2)	Pi2 (2)
TIME (min)	13	23	57	814	44	42
FLOW (m3/s)	—	—	0.1 L/min	—	—	—
re (mm)		0.43	20.9	0.43	0.43	0.43
TEMP (dC)	20.2 - 20.4	20.4 - 20.4	20.4 - 20.5	20.5 - 20.5	20.5 20.4	20.4 - 20.4
P1 (kPa)	1927 - 2200	2200 - 2047	2047 - 1850	1850 - 1392	1392 - 1392	1392 - 1392
P3 (kPa)	1919 - 1921	1921 - 1919	1919 - 1918	1918 - 1922	1922 - 1920	1920 - 1920
Panal (kPa)			612		614	614
K (m/s)			4.8E-10	4.E-10	1.1E-10	6.7E-11
L (m)			19.09	19.09	19.09	19.09
T (m2/s)			9.1E-9	8E-9	2.1E-9	1.3E-9
Ps (kPa)						
S (dim)			1.9E-2		2.8E-11	2.8E-8
Ss (1/m)			1E-3		1.5E-12	1.5E-9
FIGURES			6	7	8	9

EFFECT	RATIONALE	EFFECT	RATIONALE
TEMP. NO		FLOW NO	
BH YES	~30 days borehole full	SKIN Probably	
ANOMALY		BOUNDARY ?	

COMMENTS: (1) FLOW RESPONSE GAVE ½ SLOPE ON LOG/LOG PLOT INITIAL CONDITIONS NOT IDEAL AS PRESSURE WAS STILL FALLING & AT ≐ 1750 kPa PRIOR TO START OF TEST.
(2) EARLY TIME MATCH - DATA FALLS MORE SLOWLY BACK TO STATIC AFTER ≃ 1 MINUTE.

(*) NO COM EVENT

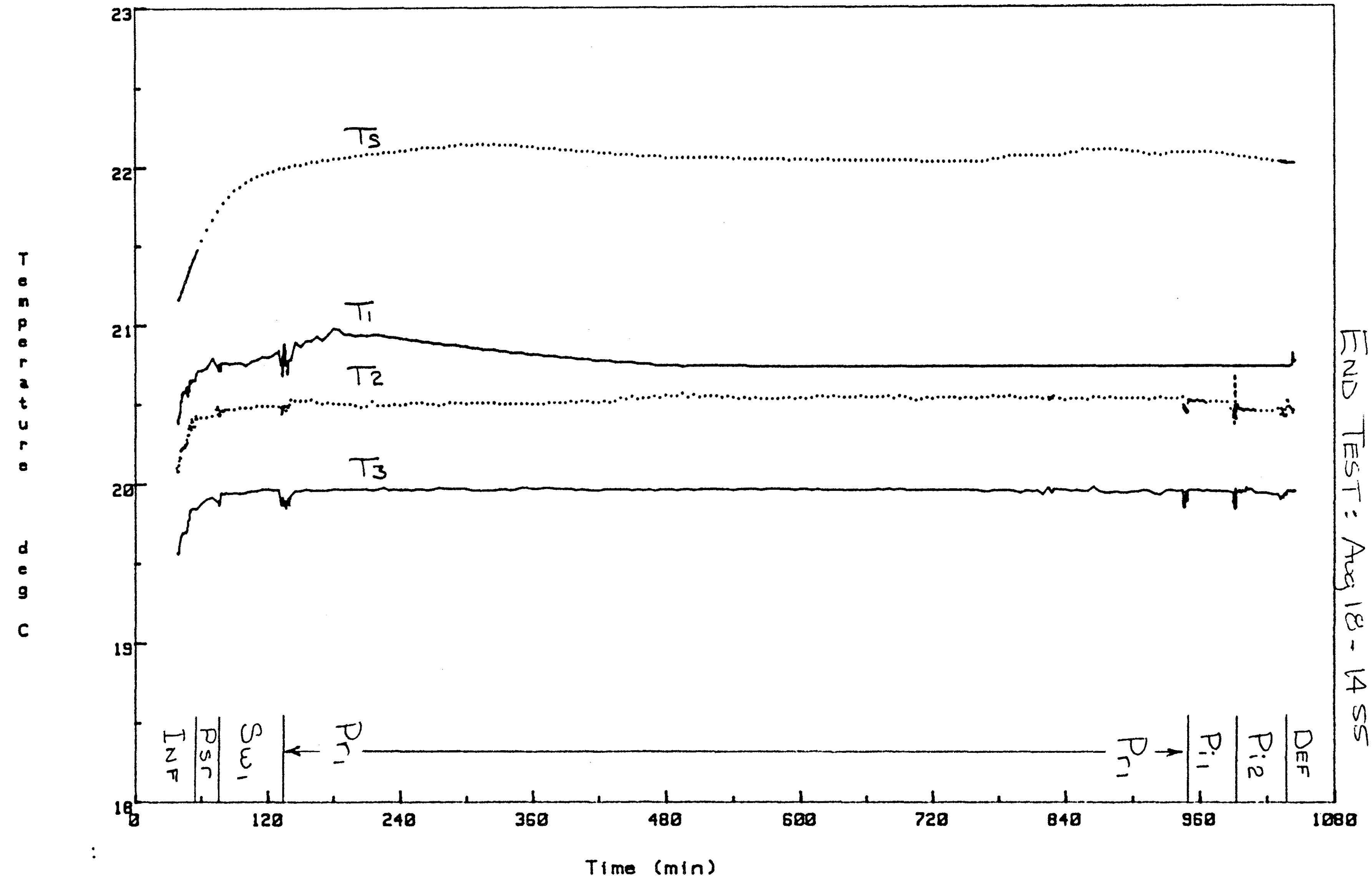
Fig 1. All Pressures Sequence - OBS3/196.5D-2



Plot start 870817213000

NAGRA/OBERBAUENSTOCK: Gartner Lee

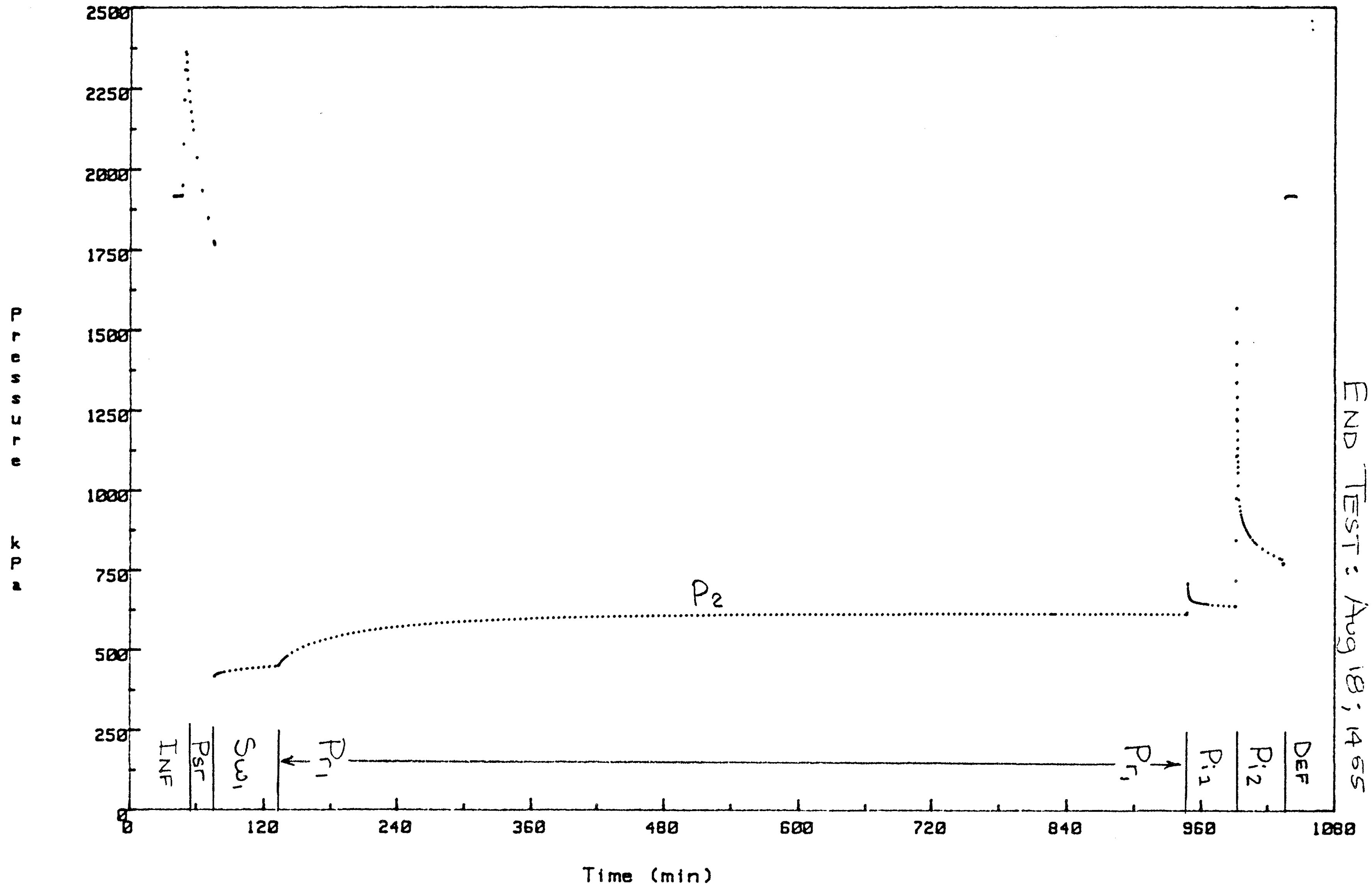
Fig 2. All Temperatures Sequence - OBS3/196.5D-2



Plot start 870817213000

NAGRA/OBERBAUENSTOCK: Gartner Lee

Fig. 3 Interval Pressure Sequence - OBS3/196.5D-2



Plot start 870817213000

P2

NAGRA/OBERBAUENSTOCK: Gartner Lee

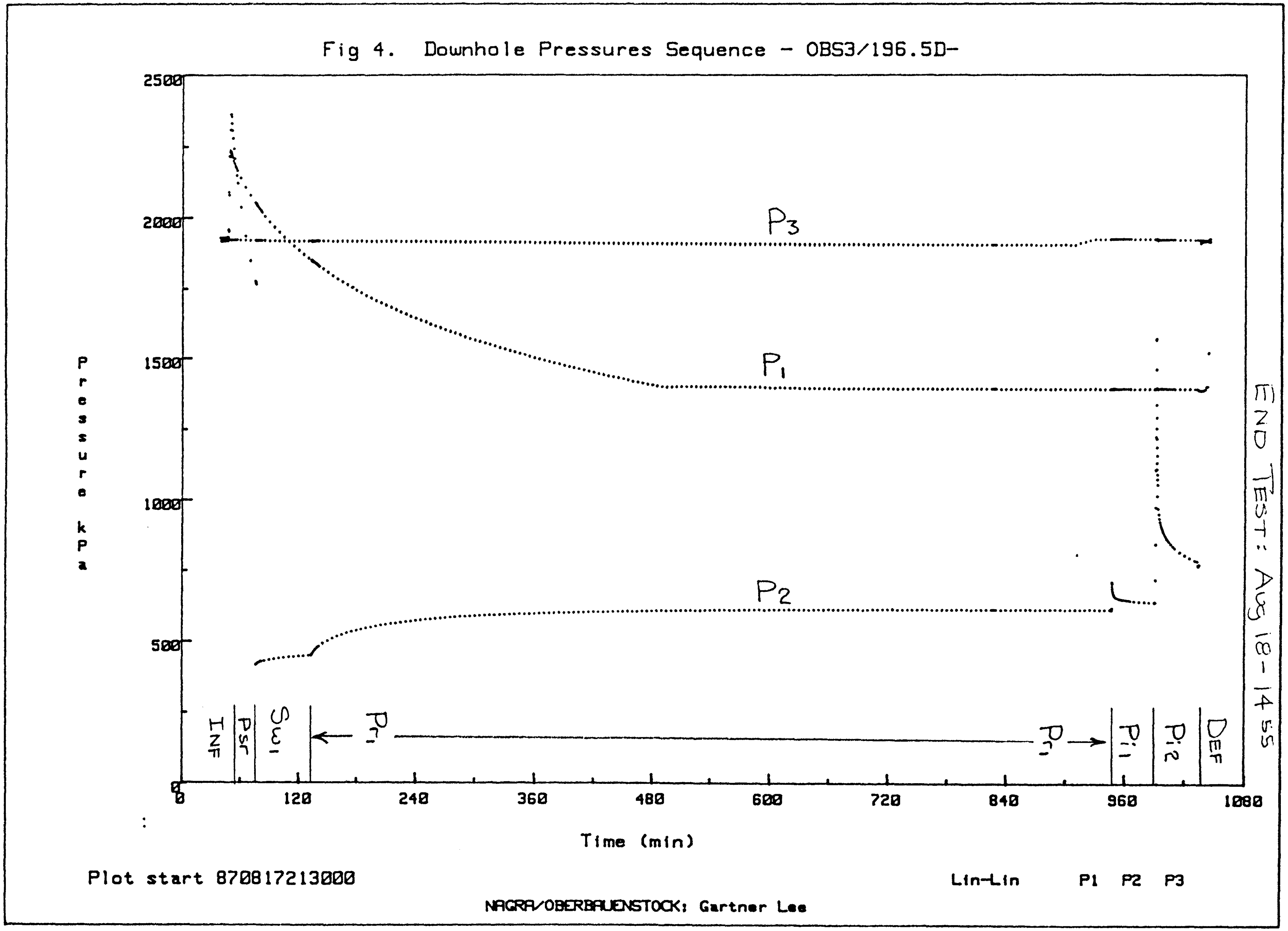
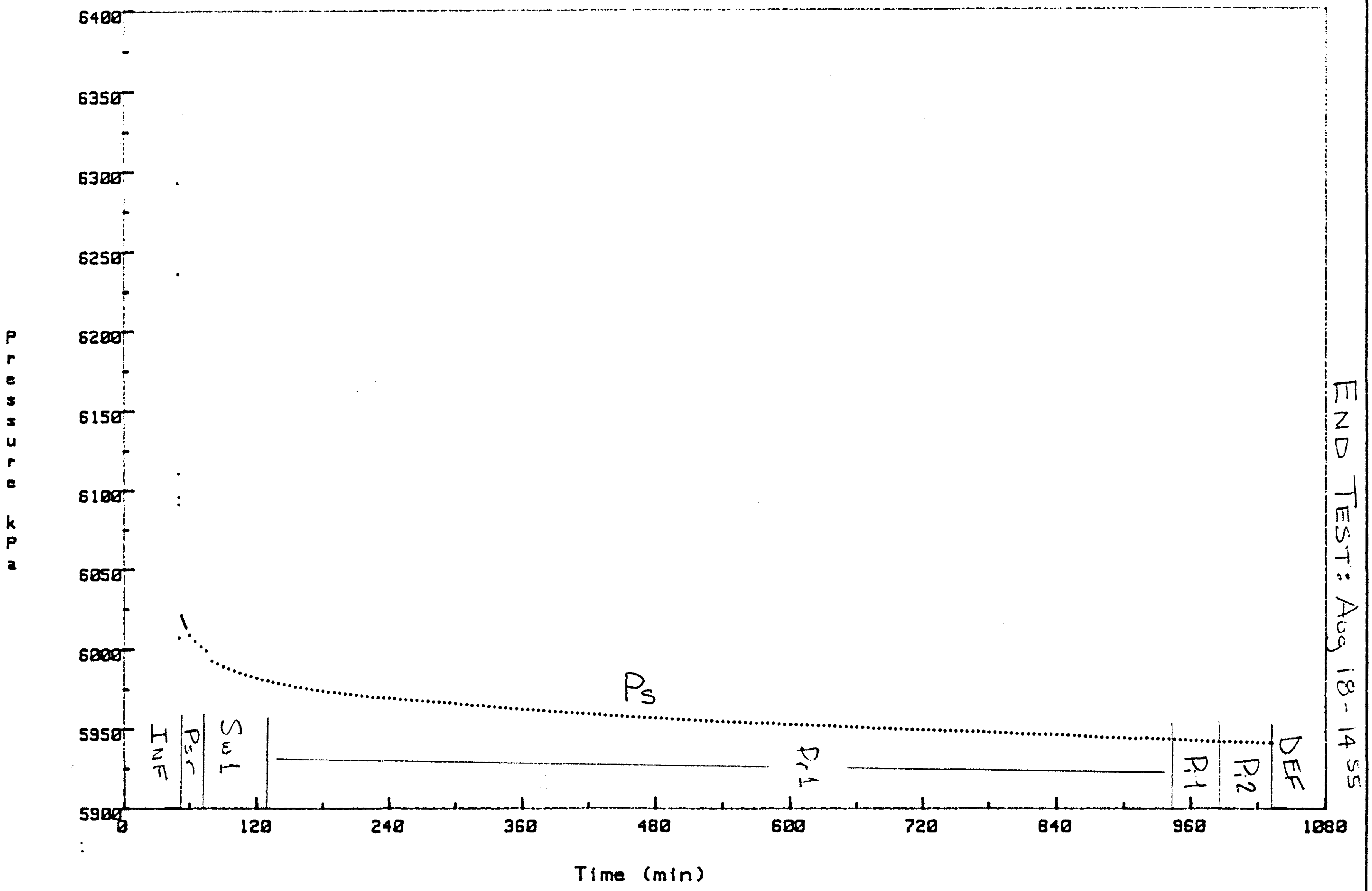


Fig 4. Downhole Pressures Sequence - OBS3/196.5D-
Pressure kPa
2500
2000
1500
1000
500
0
Time (min)
0
120
240
360
480
600
720
840
960
1080
P3
P1
P2
INF
Psr
Sw1
Pr1
Pi1
Pi2
DEF
END TEST: Aug 18 - 14 55
Plot start 870817213000
Lin-Lin
P1 P2 P3
NAGRA/OBERBAUENSTOCK: Gartner Lee

Fig 5. Packer Inflation Pressure - OBS3/196.5D-2



Plot start 870817213000

PS

NAGRA/OBERBAUENSTOCK: Gartner Lee

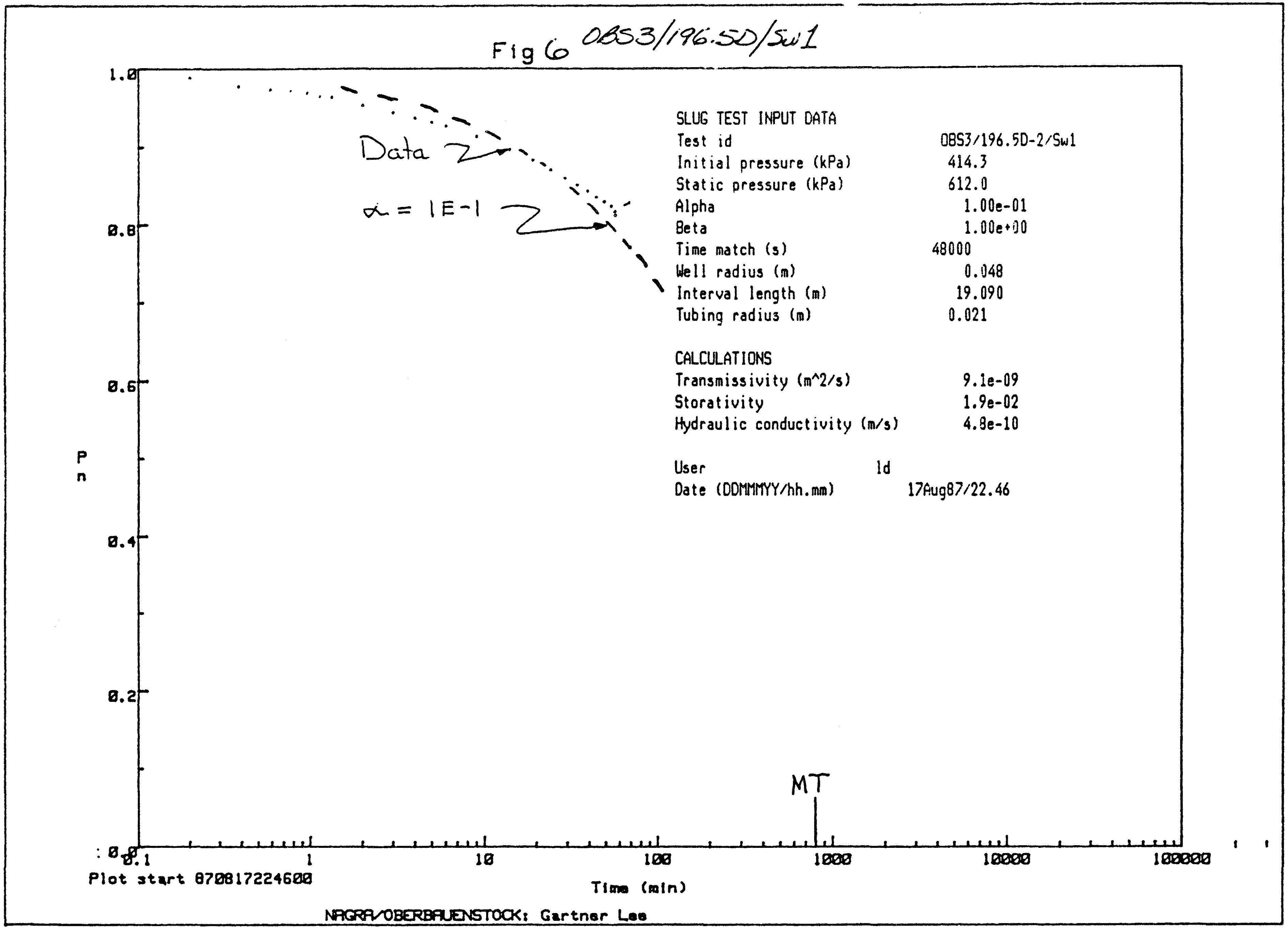


Fig 6 OBS3/196.5D/Sw1
SLUG TEST INPUT DATA
Test id OBS3/196.5D-2/Sw1
Initial pressure (kPa) 414.3
Static pressure (kPa) 612.0
Alpha 1.00e-01
Beta 1.00e+00
Time match (s) 48000
Well radius (m) 0.048
Interval length (m) 19.090
Tubing radius (m) 0.021
CALCULATIONS
Transmissivity (m^2/s) 9.1e-09
Storativity 1.9e-02
Hydraulic conductivity (m/s) 4.8e-10
User ld
Date (DDMMMYY/hh.mm) 17Aug87/22.46
Data
α = 1E-1
MT
Pn
1.0
0.8
0.6
0.4
0.2
0.0
0.1
1
10
100
1000
10000
100000
Plot start 870817224600
Time (min)
NAGRA/OBERBAUENSTOCK: Gartner Lee

Fig 7. Horner OBS3/196.5 D/Pr1

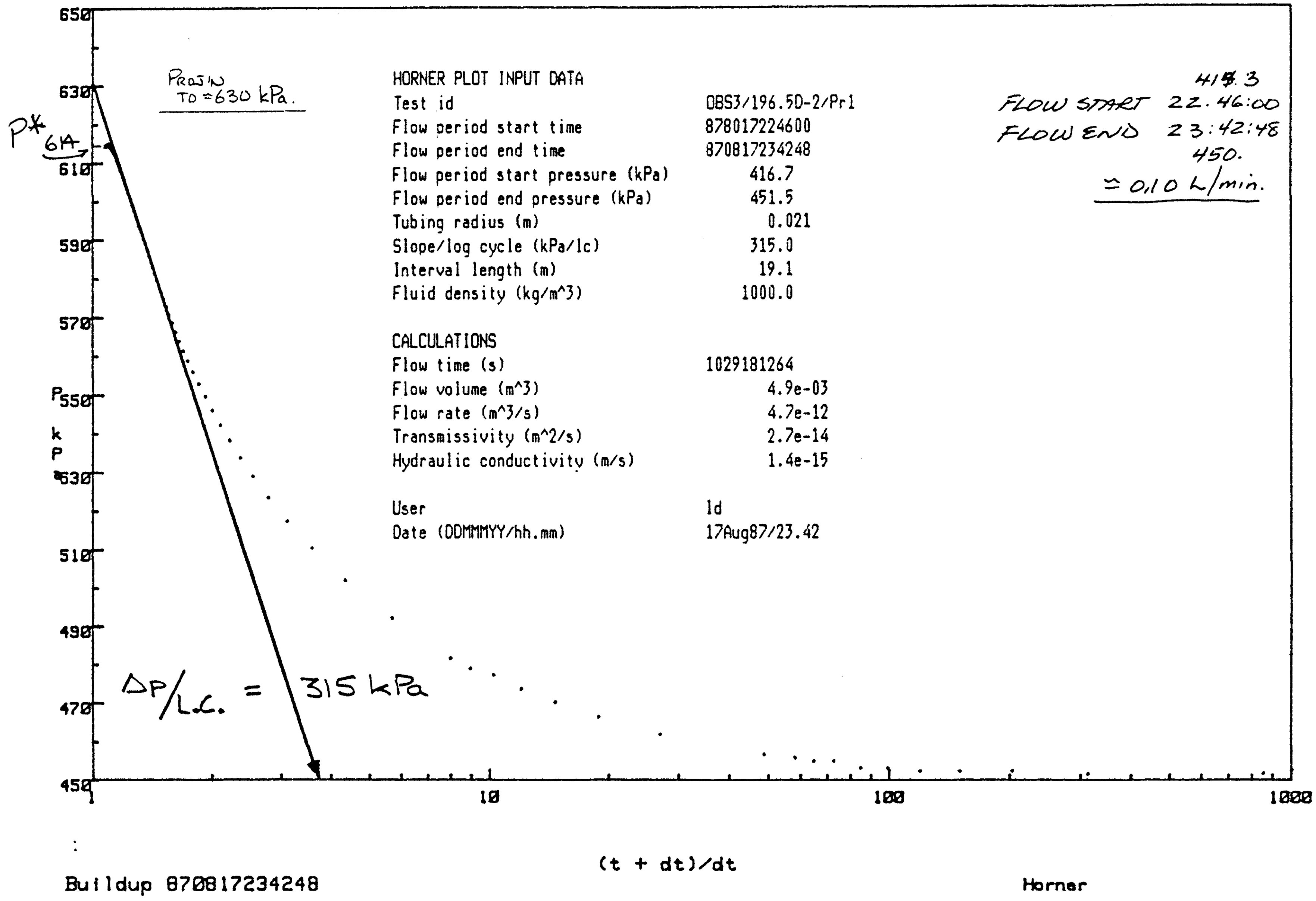


Fig 8. OBS 3 / 196.5D-2 Event Pi1

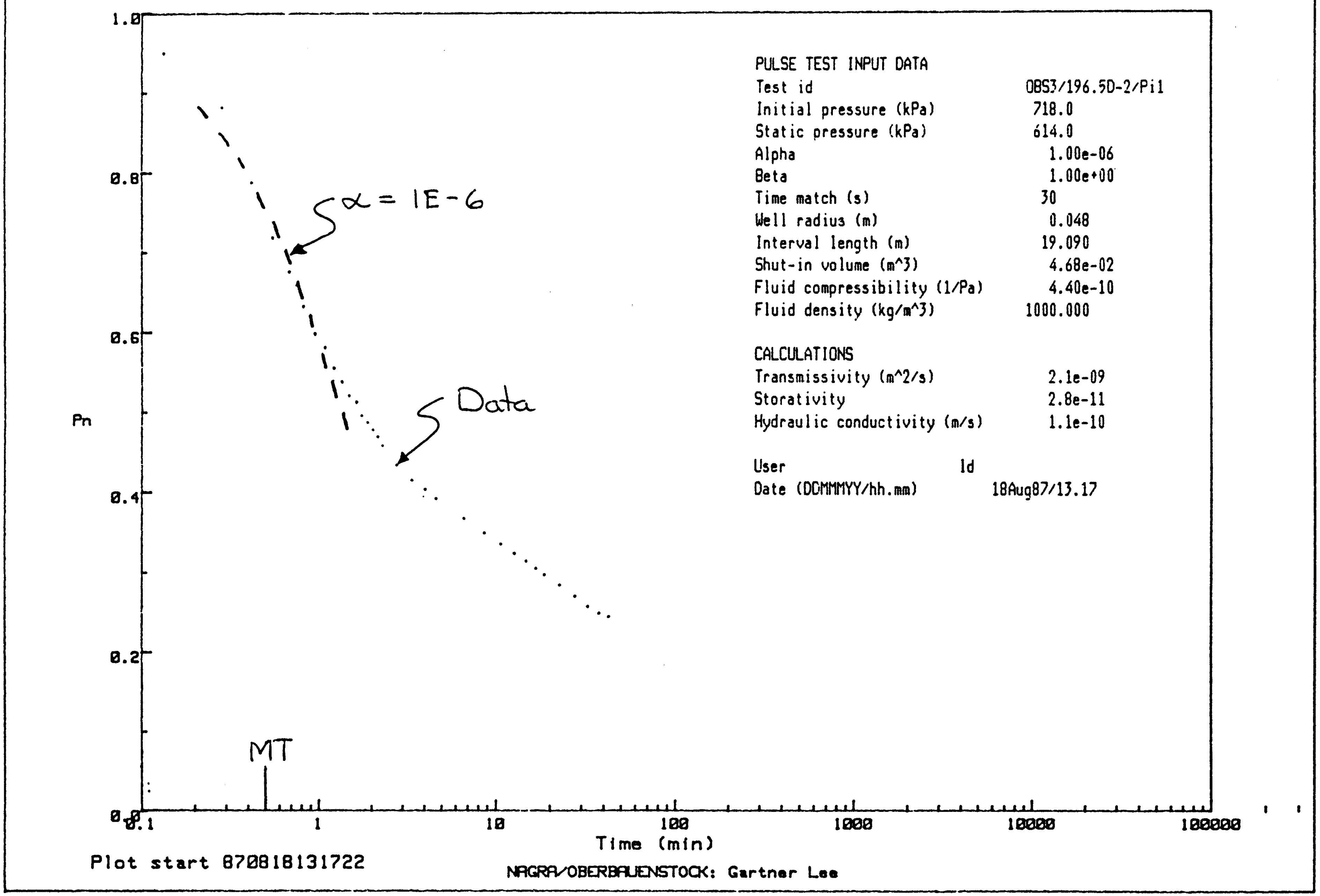
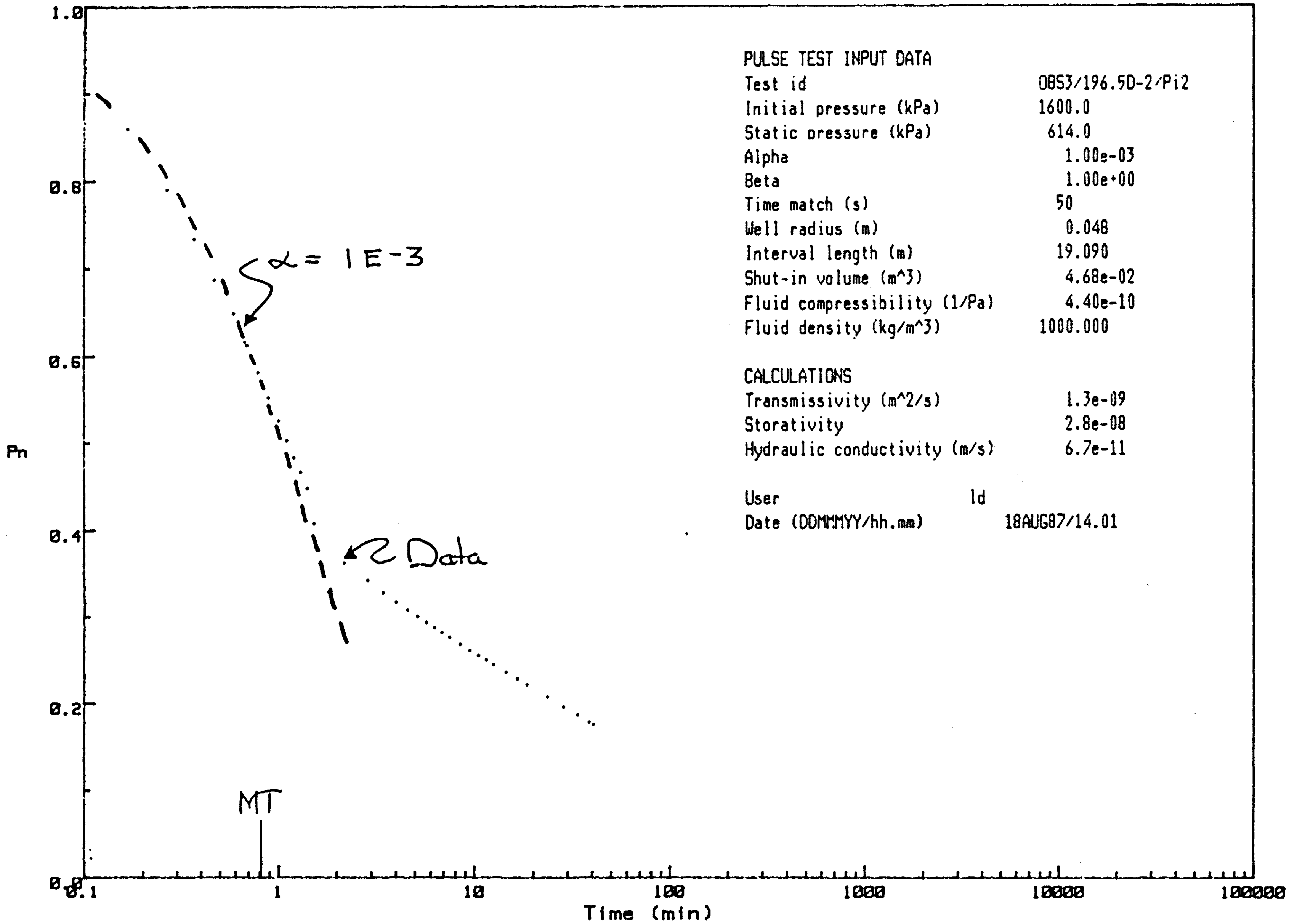


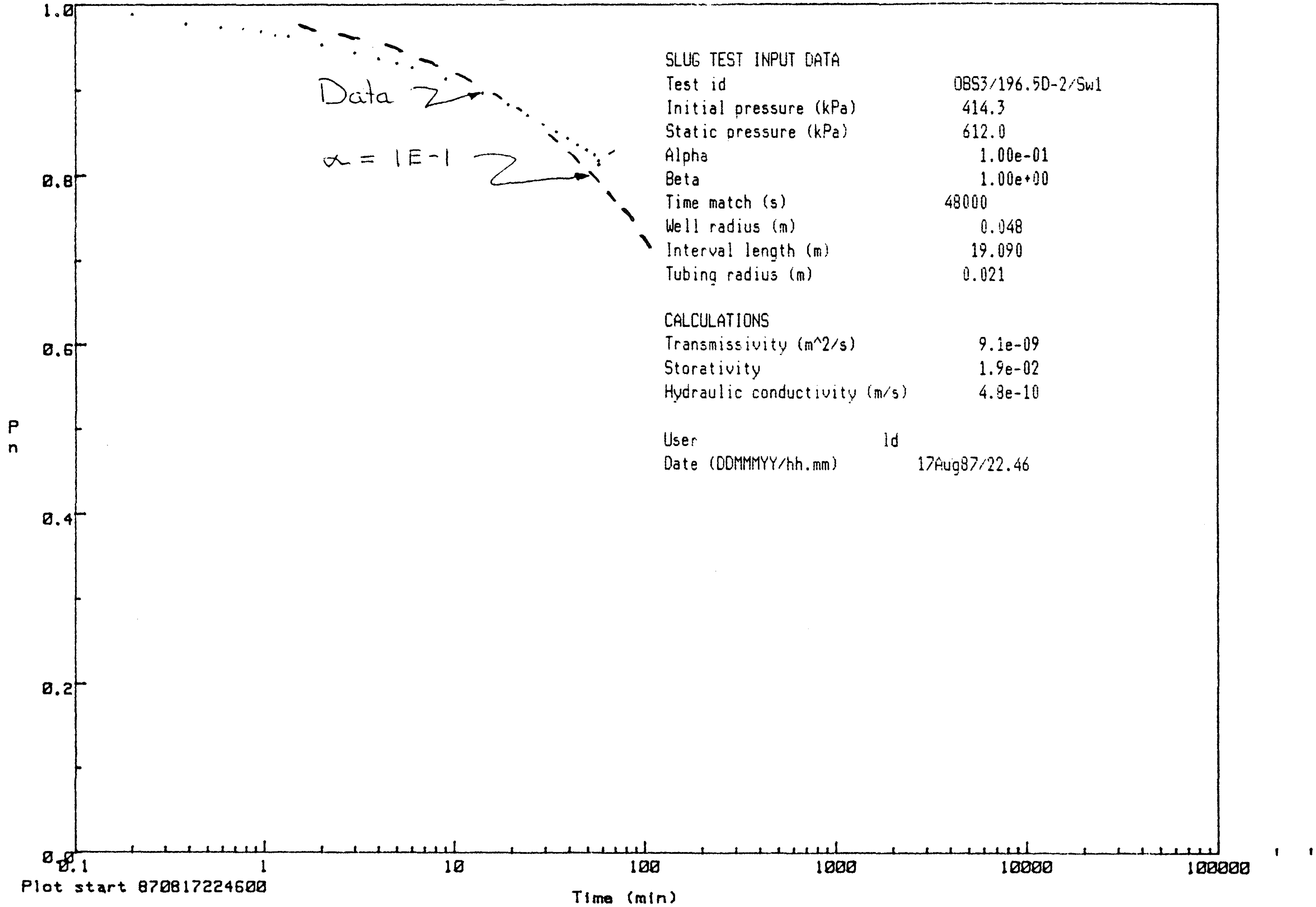
Fig 9. OBS 3 / 196.5D-2 Event Pi2



Plot start 870818140130

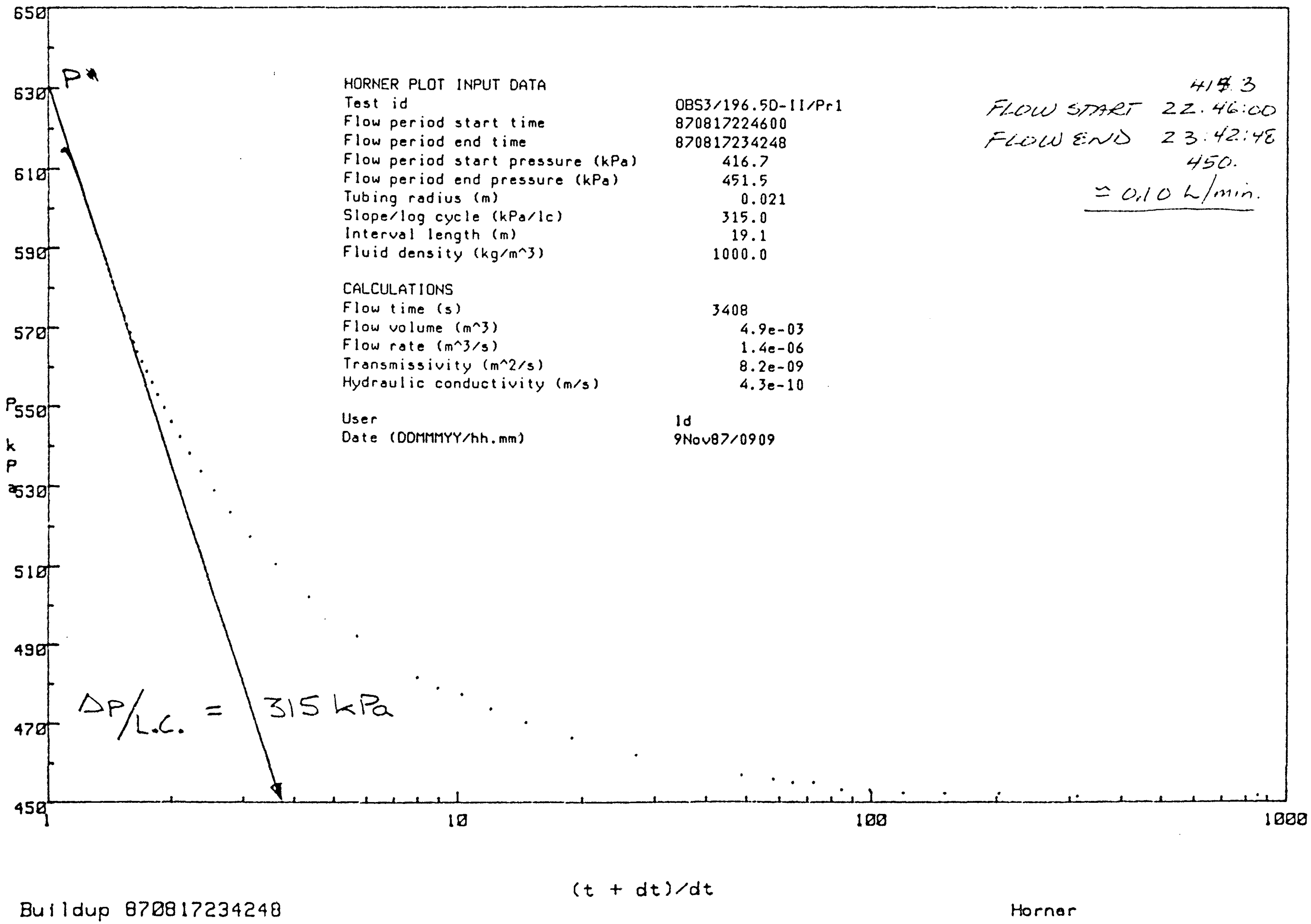
NAGRA/OBERBAUENSTOCK: Gartner Lee

QLR Fig 0BS3/196.5D/Sw1

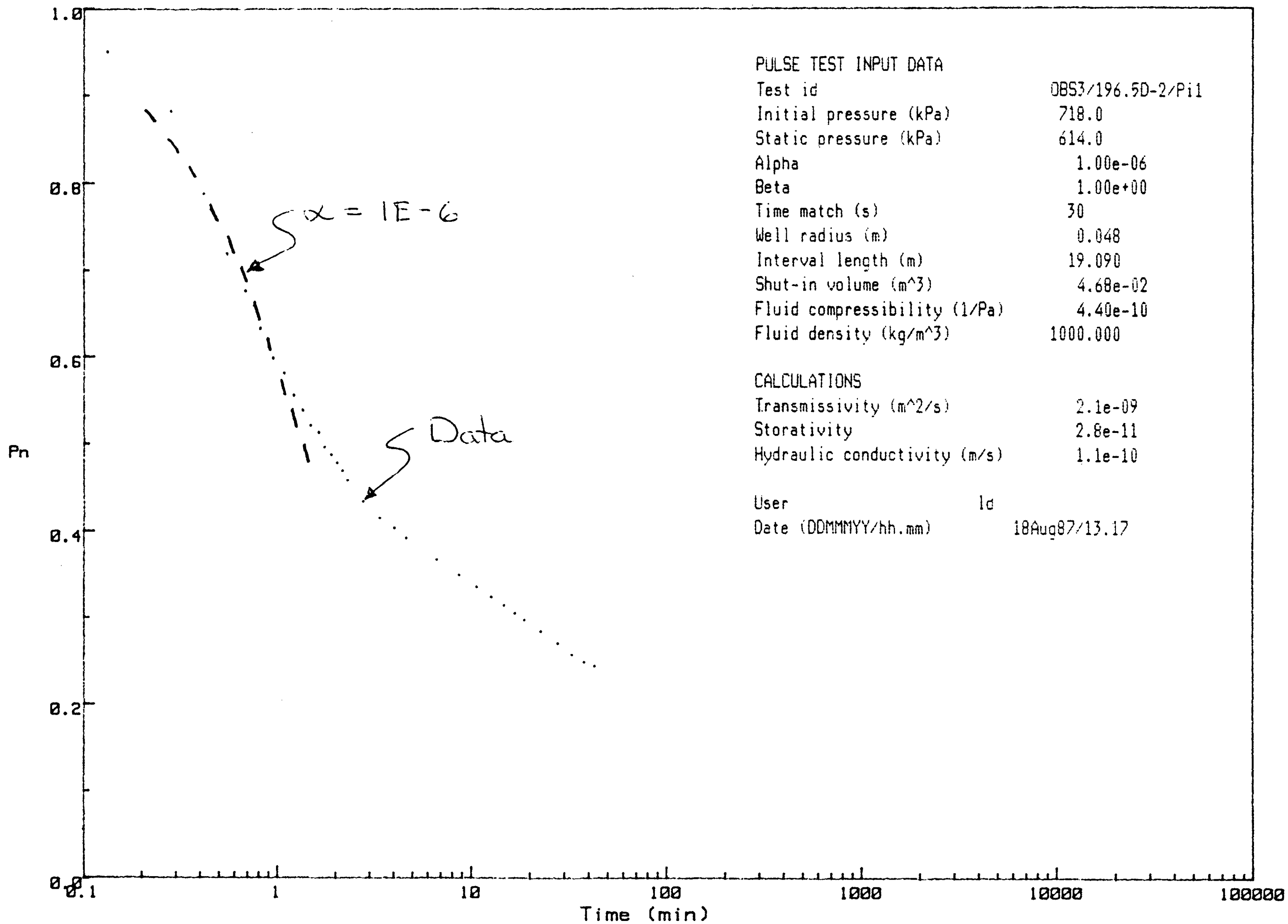


NAGRA/OBERBAUENSTOCK: Gartner Lee

QLR Fig 7. Horner OBS3/196.5 D/Pr1



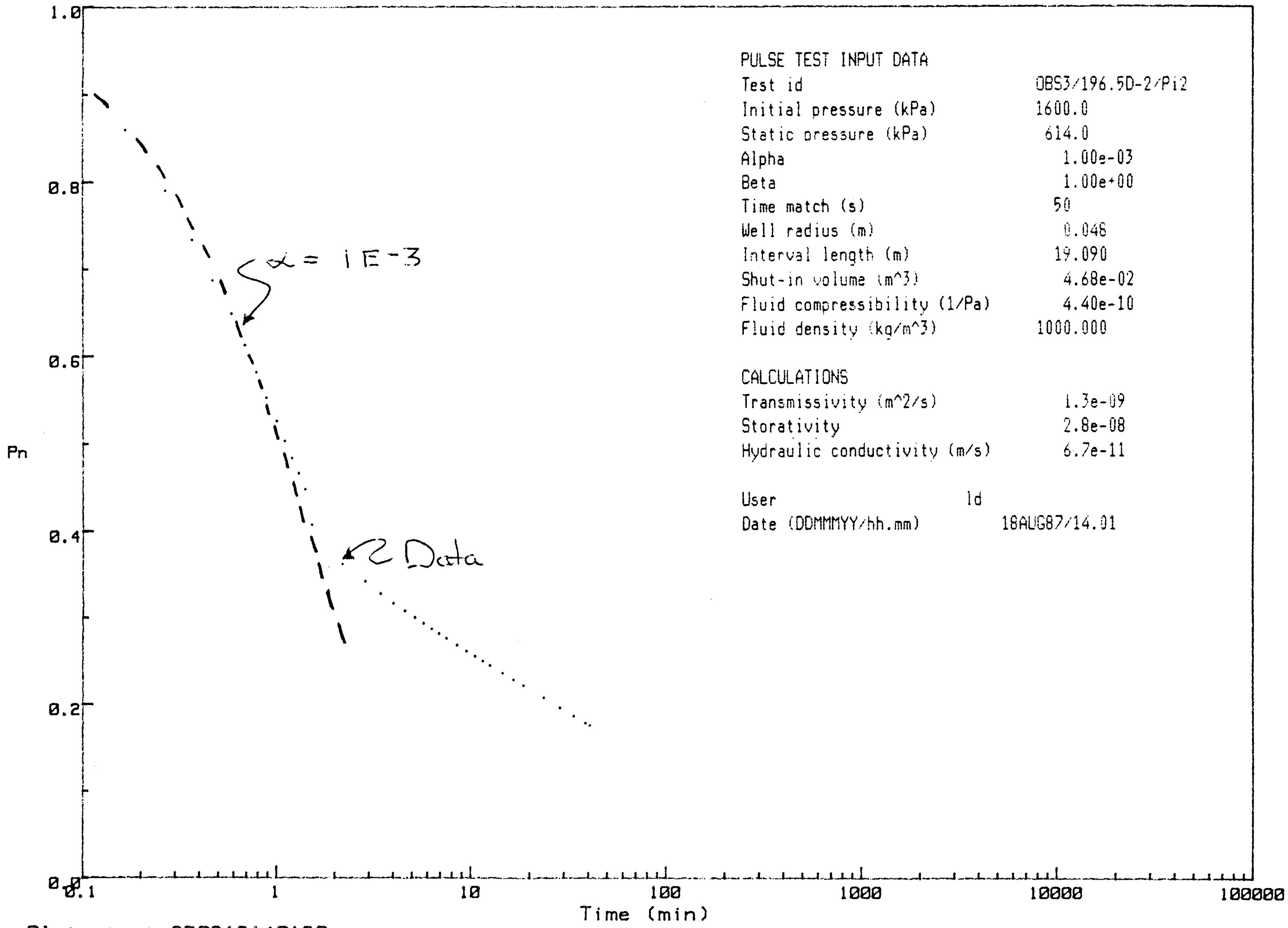
QLR Fig8. OBS 3 / 196.5D-2 Event Pi1



Plot start 870818131722

NAGRA/OBERBAUENSTOCK: Gartner Lee

QLR Fig 9. OBS 3 / 196.5D.-2 Event Pi2



Plot start 870818140130

NAGRA/OBERBAUENSTOCK: Gartner Lee

C7. APPENDIX C7: INTERVAL SA/298.0D

This interval was tested using a double straddle packer assembly with a length of 15.1 m. The upper and lower packer seats were at depths of 290.5 m and 305.6 m, respectively. Testing details are included in NIB 88-04, Section C.

C7.1 HYDROGEOLOGICAL SETTING

The interval was immediately below the marl-limestone contact and consisted of grey limestone. Highly contorted marl beds occurred in the upper 4 m with calcite infillings. Frequent fractures were closed or infilled.

This interval was the first of the detailed tests conducted after completion of drilling to total depth. The purpose of the testing was to determine the hydraulic characteristics in the vicinity of the contact area and document the static pressure.

C7.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling to 300 m,
2. Geophysical logging,
3. Drilling through the interval to total depth,
4. Geophysical logging, and,
5. Run-in of the testing equipment.

These activities lasted about 7 days prior to testing.

C7.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure C7.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Pulse injection 2	Pi2
6. Slug withdrawal 1	Sw1
7. Pressure recovery 1	Pr1
8. Deflation	DEF

C7.3.1 Interval Response

Testing began with a 68 minute compliance period during which time there was a 22 kPa decrease in pressure. The pressure drop, however, occurred because a surface fitting on the wellhead adapter plug had been closed during inflation and the pressure increased at that time. The pressure dropped when the surface fitting was loosened. Psr lasted about 7.5 hours. The pressure decreased slowly in a consistent manner by 17 kPa from 2964 to a final value of 2947 kPa. The tubing fluid level was blown down and refilled to verify that the FAV was closed for this event. Initial expectations had been that the pressure would decrease more rapidly than occurred.

Pi1 was done using the FAV and recovered by about 90 percent in 100 minutes and was terminated at a pressure of 2967 kPa. A second pulse test, Pi2, was done again using the FAV but with a higher initial overpressure of 3705 kPa. This test lasted 135 minutes and recovered to about 2157 kPa.

Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 2097 kPa at the start of Sw1. An underpressure was used to see if fluid would flow up into the tubing. An increase of 61 kPa was recorded during 268 minutes at which time the pressure was 2158 kPa. The flow period response was faster than had been expected based on the pulse test responses.

The FAV was closed and the final pressure buildup was monitored. Pr1 was monitored for 10 hours. The pressure increased by only 233 kPa to a final value of 2391 kPa and was increasing slowly at the end of testing in the interval.

C7.3.2 Annulus Response

The pressure decreased during testing. Exact values are not useful, however, since spillage occurred into the annulus during preparation for some of the other events. The pressure at the end of testing was about 2900 kPa.

C7.3.3 Bottomhole Response

The P1-line surface valve was closed downhole and therefore the line hydraulics did not affect the response. The pressure began to decrease shortly after the beginning of inflation as the packers sealed against the borehole wall. In this testing, there was only about 43 m of borehole below the bottom packer. Pressures decreased rapidly to about 2450 kPa after one hour of testing. Pressures continually decreased over the duration of testing to a final value of 2399 kPa.

The rapid response in the bottomhole zone suggested that this straddled interval was less permeable than the bottom of the borehole.

C7.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It decreased by about 30 kPa over the 28 hour testing period.

C7.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 22.7°C and 123.6°C. The surface probe temperature varied between 21.2°C and 23.9°C.

C7.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

C7.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The first two pulse tests had responses that indicated conductivity values on the order of 1e-11 m/s. However, that amount of flow that occurred during the initial part of Sw1 indicated a higher value of about 3e-10 m/s. The later Sw1 data however, deviated from the type-curve match and suggested a lower value. The Pr1 buildup data was plotted but the analysis result was not accurate since the preceding Sw1 event had not reached infinite acting radial flow conditions.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig C7.2.

No value of static pressure could be determined from the testing for this interval since the zone response was not consistent. However, a value of 2400 was extrapolated from both the bottomhole data and the results of a subsequent test in the SA/311.0D interval. Accordingly, an initial value of 2400 kPa was used for static pressures in the simulations.

C7.4.2 Results

Borehole history pressures were about 3000 kPa during most of the borehole history period which had lasted about 7 days. The drilling and annulus fluid level during the logging activities affected the pressures in the vicinity of the borehole prior to and during testing. This combined with the inconsistent interval response and lack of bounding meant that a value of static pressure considered representative of interval conditions would have to be estimated from other borehole data.

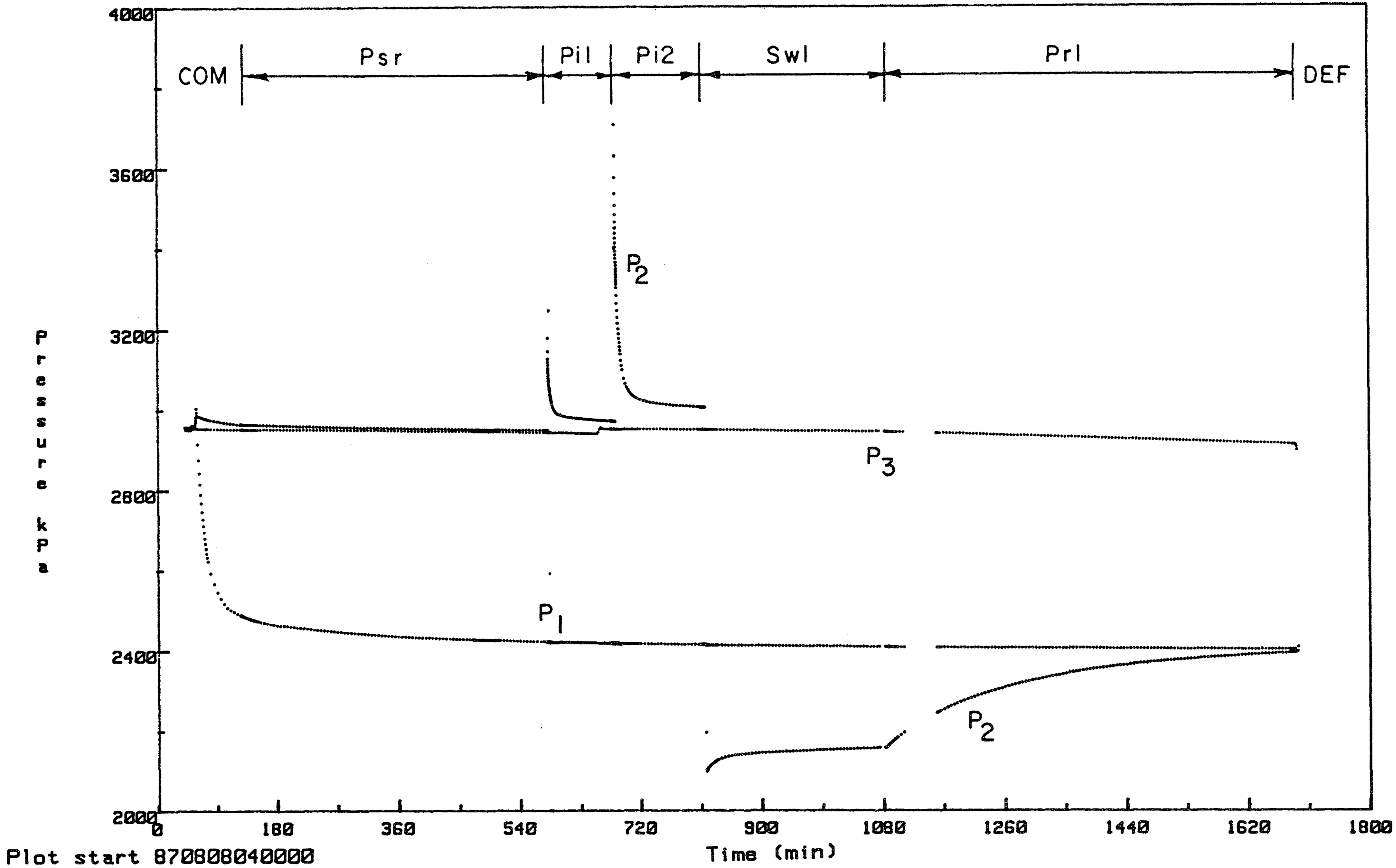
The pressure value of 2400 kPa used was consistent with testing values from the adjacent interval. Because of the inconsistent response during testing, however, it is difficult to assess whether this value provided confirming results. Based on the results from other intervals, a reasonable static pressure value would be between 2300 and 2500 kPa. The hydraulic head elevations of these pressures would be very similar to the Lake Uri level of 433 m (asl).

Attempts to bound the data with a single set of parameter values were not successful. The Psr and Pi1 events were able to be bounded using hydraulic conductivity values between 1e-12 m/s and 1e-11 m/s. However, values as high as 1e-9 m/s were required to generate the flow observed during Sw1. No consistent parameter values bounded all the tes data.

The interval responded as if it had either a positive skin effect that was reduced during the underpressuring of Sw1, or, a limited size and extent. A positive skin effect could account for the slower response during the pulse tests compare to the flow period. This assumes that the underpressure caused the borehole wall 'invasion' was overcome when it was subjected to the underpressure. A skin developed earlier during drilling would also have limited the extent to which the borehole history pressures were transmitted away from the wellbore. This could account for the slower pressure buildup response and the lower Pr1 end pressure compared to the pulse test end pressure values.

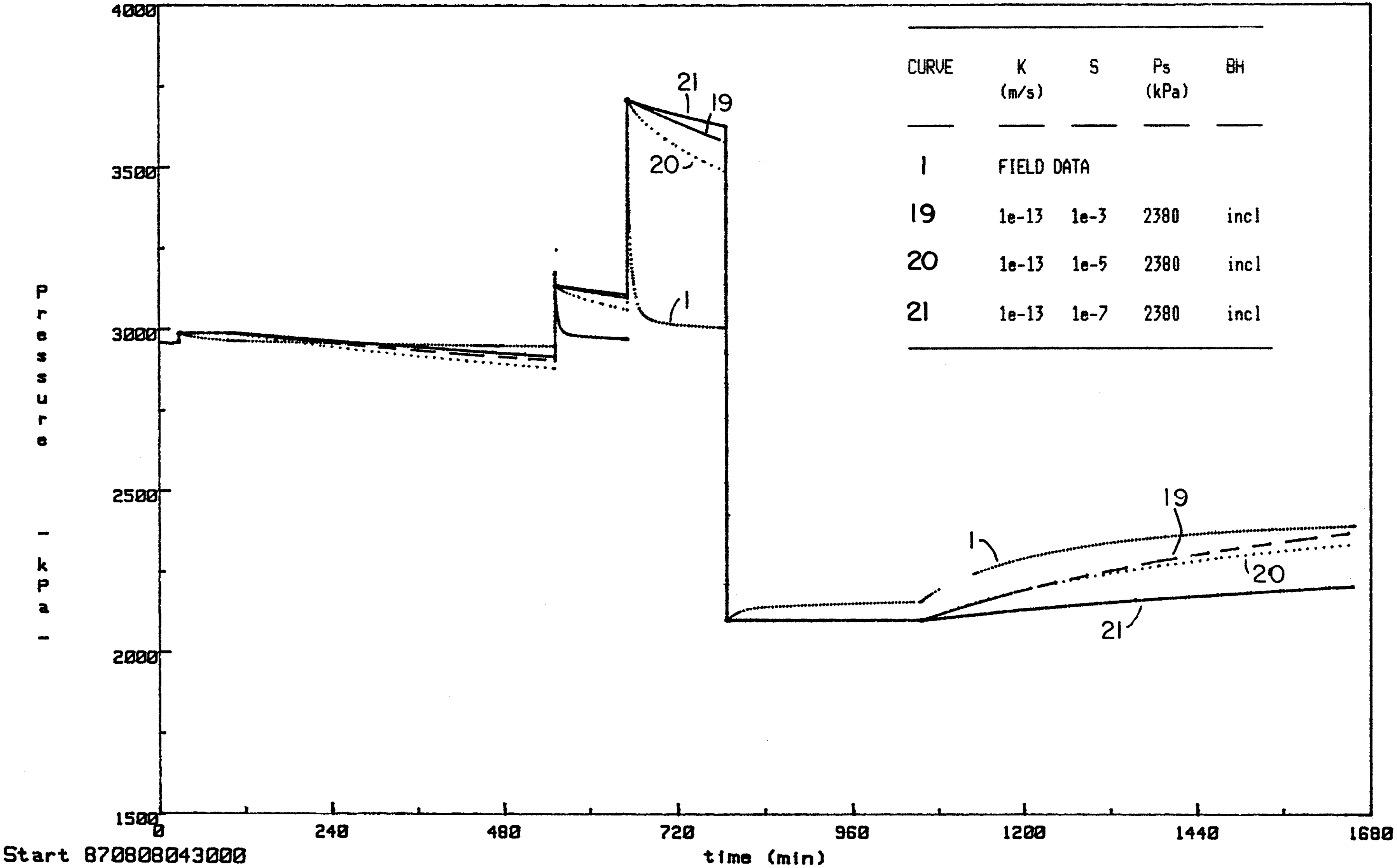
A limited extent reservoir could account for the continually increasing end pressures following eac injection period, and the lower pressures at the end of the slug flow and final buildup event. Fluid released from storage could account for the part of the flow that occurred during Sw1.

The interval did not respond like the model used t assess it's characteristics. At this time, withou additional more detailed analysis, either of the two above conditions are possible.



NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C7.1

PRESSURE SEQUENCE PLOT - SA/298.0D



CURVE	K (m/s)	S	Ps (kPa)	BH
1	FIELD DATA			
19	1e-13	1e-3	2380	incl
20	1e-13	1e-5	2380	incl
21	1e-13	1e-7	2380	incl

NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C7.2

EXAMPLE SIMULATION - SA/298.0D

C8. APPENDIX C8: INTERVAL SA/311.0D

This interval was tested using a double straddle packer assembly with a length of 15.1 m. The upper and lower packer seats were at depths of 303.5 m and 318.6 m, respectively. Testing details are included in NIB 88-04, Section D.

C8.1 HYDROGEOLOGICAL SETTING

The interval was located in the Valanginian Kalk immediately above the contact with the Tertiary sandstone. The lower half of the interval showed an increasing sand content. Fracture density was about 50 per meter, with the fractures primarily infilled or closed. Two open fractures were recorded at depths of 307 and 309 m. RQD ranged from 50 to 100 percent.

This interval was the second of the detailed tests conducted after completion of drilling to total depth. It was the deepest interval tested during the entire OBS-1 program. The purpose of the testing was to determine the hydraulic characteristics in the vicinity of the contact area and document the static pressure. The previous SA/298.0D interval did not yield a static pressure value.

C8.2 BOREHOLE ACTIVITY SUMMARY

Activities opposite the interval prior to testing were:

1. Drilling through the interval to total depth,
2. Geophysical logging, and,
3. Run-in and testing 298.0D.

These activities lasted about 5 days prior to testing.

C8.3 TESTING ACTIVITY SUMMARY

The testing events, as shown in Figure C8.1, included:

1. Inflation	INF
2 Compliance	COM
3. Shut-in static recovery	Psr
4. Pulse injection 1	Pi1
5. Slug withdrawal 1	Sw1

6. Pressure recovery 1 — Pr1
7. Deflation — DEF

C8.3.1 Interval Response

Testing began with a 69 minute compliance period during which time there was a 39 kPa decrease in pressure corresponding to a fluid level fall in the tubing. The final pressure was 2998 kPa. Psr lasted about 6 hours. The pressure decreased relatively rapidly but decayed in a consistent manner. The total pressure falloff was 478 kPa to a final value of 2519 kPa.

Pi1 was done using the FAV and recovered by about 98 percent in 85 minutes. Most of the fluid in the tubing was removed and the zone subjected to an initial pressure of 2233 kPa at the start of Sw1. An underpressure was used to see if fluid would flow up into the tubing. An consistent and steady increase of 124 kPa was recorded during 250 minutes at which time the pressure was 2357 kPa.

The FAV was closed and the final pressure buildup was monitored. Pr1 was monitored for 13 hours. The pressure increased by 148 kPa to a final value of 2505 kPa and was increasing slowly at the end of testing in the interval.

C8.3.2 Annulus Response

The pressure decreased by about 80 kPa during testing.

C8.3.3 Bottomhole Response

The P1-line surface valve was closed downhole and therefore the line hydraulics did not affect the response. The pressure increased to about 3300 kPa as a consequence of packer squeeze in the bottomhole section. It gradually and consistently fell over the testing period to a final value of about 2870 kPa.

The slow response in the bottomhole zone suggested that this straddled interval was the one that had accounted for the bottomhole response during the SA/298.0D test.

C8.3.4 Packer Pressure Response

The packer line pressure was maintained constant at surface with a regulator and bottled nitrogen. It increased by about 400 kPa over the 25 hour testing period.

C8.3.5 Temperature Response

Temperatures at sensor depth remained relatively stable between 22.9°C and 23.9°C. The surface probe temperature varied between 20.9°C and 21.7°C.

C8.4 INTERPRETATION AND RESULTS

The drilling and previous testing pressures are relatively well documented. The higher pressures opposite the interval likely influenced the formation response during testing.

C8.4.1 Analysis Procedure

The borehole history data were compiled and the pressure prior to testing in the interval was estimated relative to the P2 transducer. No temperature effect occurred.

Early time plots were made to extrapolate the initial conditions of each event. Analyses of the QLR report were reviewed. The Pi1 event indicated a conductivity on the order of 5e-11 m/s. However, that amount of flow that occurred during the initial part of Sw1 indicated a higher value of about 2e-9 m/s. Both sets of data fit well with the type curves at reasonable storativity values.

The Pr1 buildup data was plotted but the analysis result may not have been accurate since there was uncertainty in picking the correct straight line and since the preceding Sw1 event may not have reached infinite acting radial flow conditions. Overall, however, except for the Pi1 event, the response conditions suggested a conductivity on the order of about 1e-9 m/s.

The GLIMPSE model was used to attempt to bound the interval data. A simulation run demonstrating the approach is shown in Fig C8.2.

Static pressure estimates were made based on the extrapolated pressure data from the Psr, Pi1 and Pr1 events. These data confirmed the values from the P1 pressures during the prior SA/298.0D interval testing. Accordingly, an initial value of 2505 kPa was used for static pressures in the simulations.

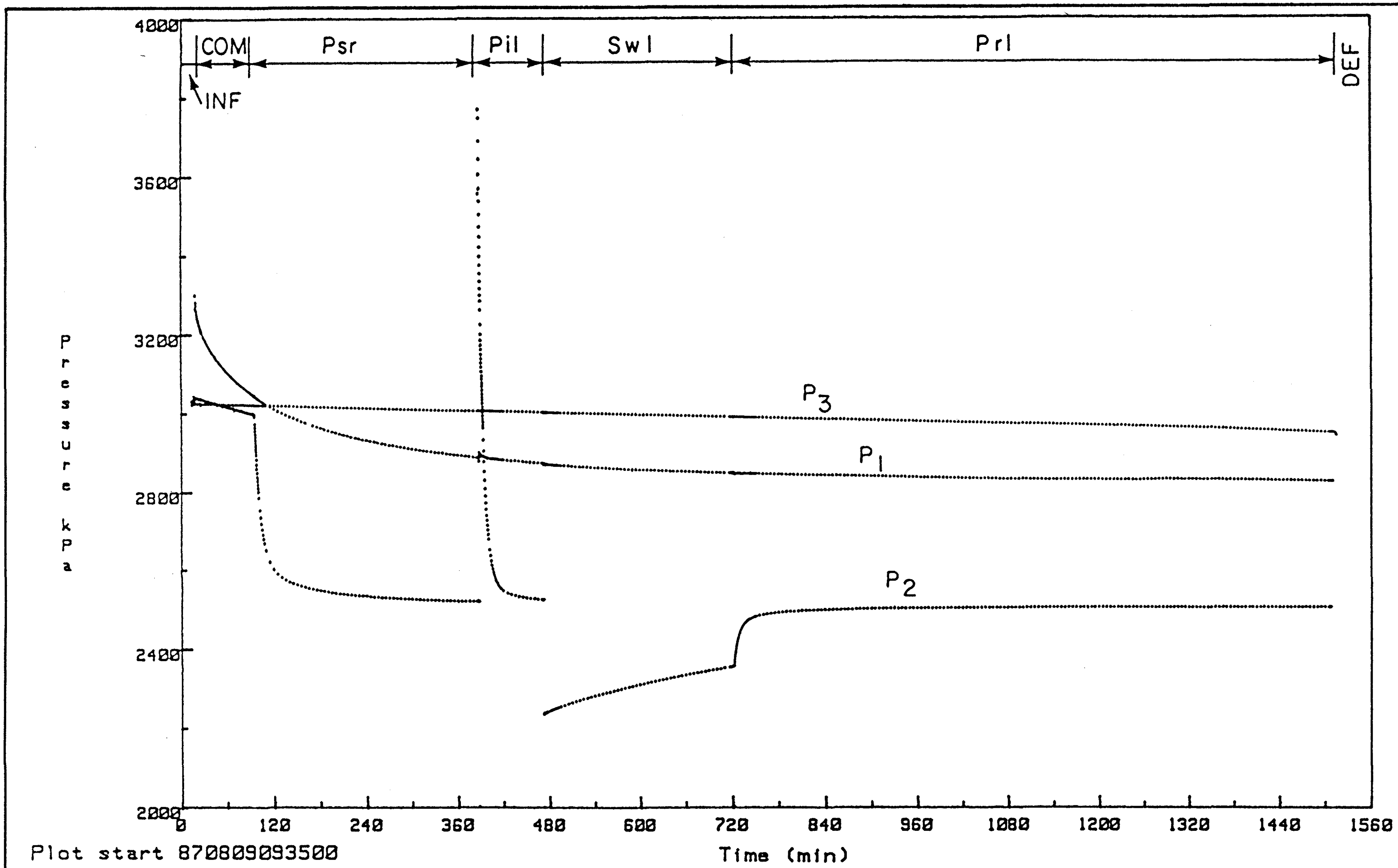
C8.4.2 Results

Borehole history pressures were about 3100 kPa during most of the drilling and logging which had lasted about 4 days. The pressure dropped to between 2400 and 2500 kPa during the SA/298.0D testing. The pressures during during these activities affected the pressures in the vicinity of the borehole prior to and during testing.

The pressure value of 2450 kPa was required to bound the data when the borehole history data was included. The hydraulic head elevations of this pressure would be 341 m (asl), very similar to the Lake Uri level of 433 m (asl).

Attempts to bound the data with a single set of parameter values were successful. The discrepancy between the Pi1 and Sw1 type curve matching values in part may have resulted from the open period prior to closing the FAV not being accounted for in the standard analysis approach. Conductivity values between 1e-9 and 5e-9 m/s with storativity in the range of 1e-7 to 1e-3 were used with a static pressure of 2450 kPa.

The 2450 Kpa pressure used to bound the data was about 50 kPa lower than the 2500 kPa consistent actual and extrapolated end pressures of the shut-in events during testing. This suggests that the influence of the borehole history pressures extended through the testing.



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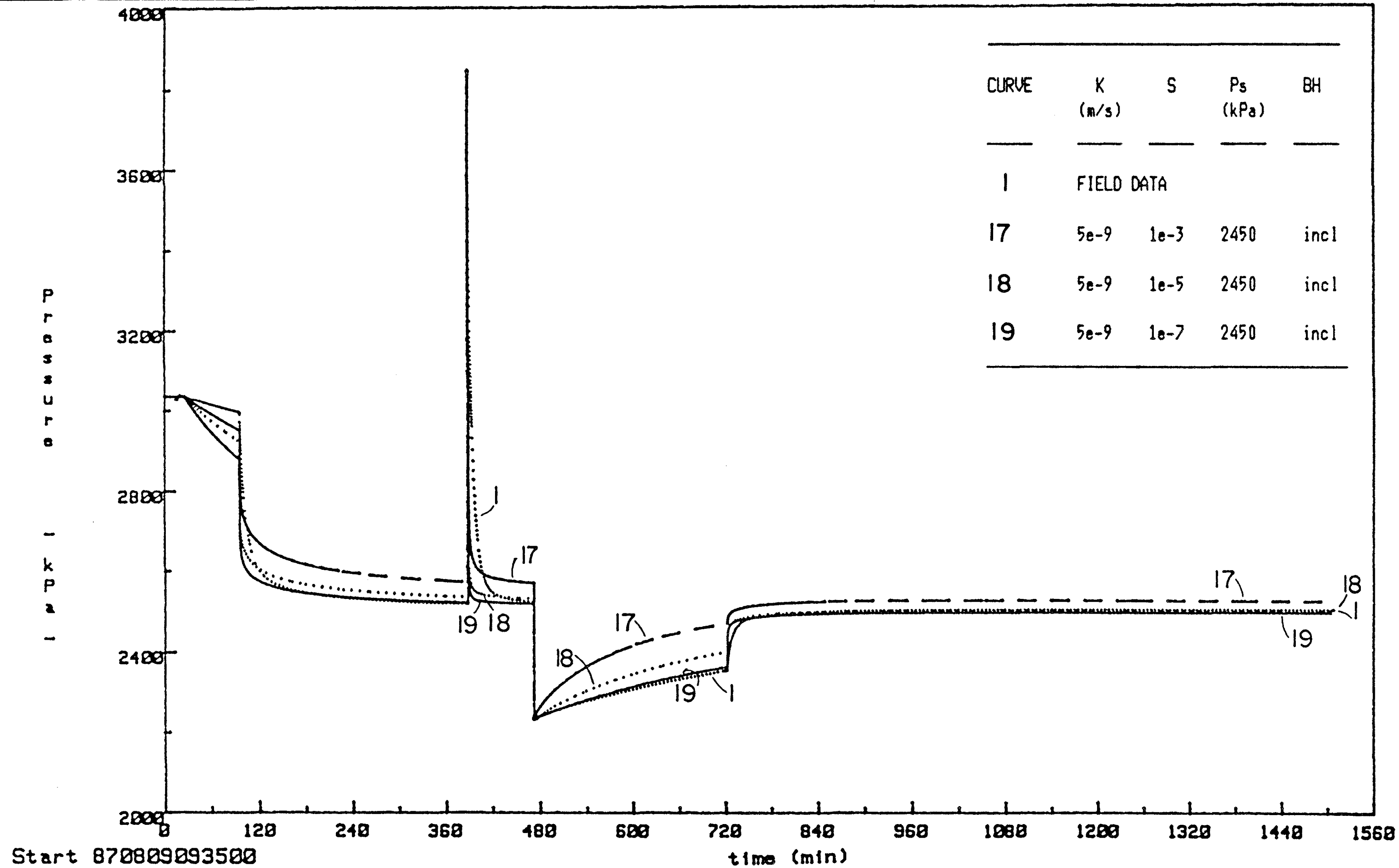
PRESSURE SEQUENCE PLOT - SA/311.0D



CURVE	K (m/s)	S	Ps (kPa)	BH
1	FIELD DATA			
17	5e-9	1e-3	2450	incl
18	5e-9	1e-5	2450	incl
19	5e-9	1e-7	2450	incl

NAGRA / GLAG	NTB: 88-03	OBERBAUENSTOCK	DAT.: APR. 88	C8.2

EXAMPLE SIMULATION - SA/311.0D