FLEXIBILITY

ADDITIONAL INFORMATION ON THE SITING PROPOSAL

Processes in the earth’s crust and at the surface lead to stresses below ground and can result in deformation of the rock. Faults form where layers of rock move against each other. These are considered to be geological weak points. Large, connected areas without major faults are advantageous as they allow more flexibility for the layout of a deep geological repository. Faults and folds can be identified and mapped comprehensively using 3D seismics. For this reason, subsurface seismic imaging and its geological interpretation form an important basis for assessing the degree of flexibility for repository layout planning.

The present document supplements the report on the siting proposal with more detailed information on the topic of flexibility. In the first part, the regional tectonic setting is presented in an overview map of Northern Switzerland. This is followed by a comparison of the three siting regions based on 3D seismic data: first the uninterpreted seismic image and then the structural geological interpretation. For a better understanding of the interpretation, examples of the different structure types are shown as block images based on 3D seismic data.

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OVERVIEW OF REGIONAL TECTONIC ELEMENTS

In the geological past, regional tectonic elements have absorbed most of the displacements and represent weakness zones that are avoided in the placement of the repository. As in Stage 2 of the Sectoral Plan process (SGT), this document distinguishes between two types of regional tectonic elements: regional fault zones and tectonic zones to be avoided. The former include extended fault zones in the kilometre range with clear vertical offsets in the Mesozoic strata. Tectonic zones to be avoided were identified, on the one hand, in the vicinity of large post-Palaeozoic reactivated basement faults, namely in the margins of the Permo-Carboniferous Trough of Northern Switzerland, and, on the other hand, in larger, compressively overprinted areas (e.g. margins of the Folded Jura).

Thanks to the new 3D seismic data, the overview map depicting the extension of the regional tectonic elements could be refined compared to Stage 2 of the Sectoral Plan, especially in the southern part of the Jura Ost (JO) siting region and in the northern part of the Nördlich Lägern (NL) siting region (Figure 1). As opposed to the approach for Stage 2 of the Sectoral Plan, no general safety distance was included when delineating the regional fault zones. This will now be considered in conjunction with repository layout planning.

The Jura Ost siting region is located immediately north of the Folded Jura, a tectonic compression zone that was formed as a result of the alpine orogeny. The impact of this compression can be recognised comparatively well here. A compressional event such as this also affected Nördlich Lägern, but to a lesser extent and with a smaller impact on the Opalinus Clay. While Zürich Nordost (ZNO) was least exposed to this compressional deformation, it is located very near the Hegau-Bodensee Graben, which continues to be a seismically active expansion zone today.

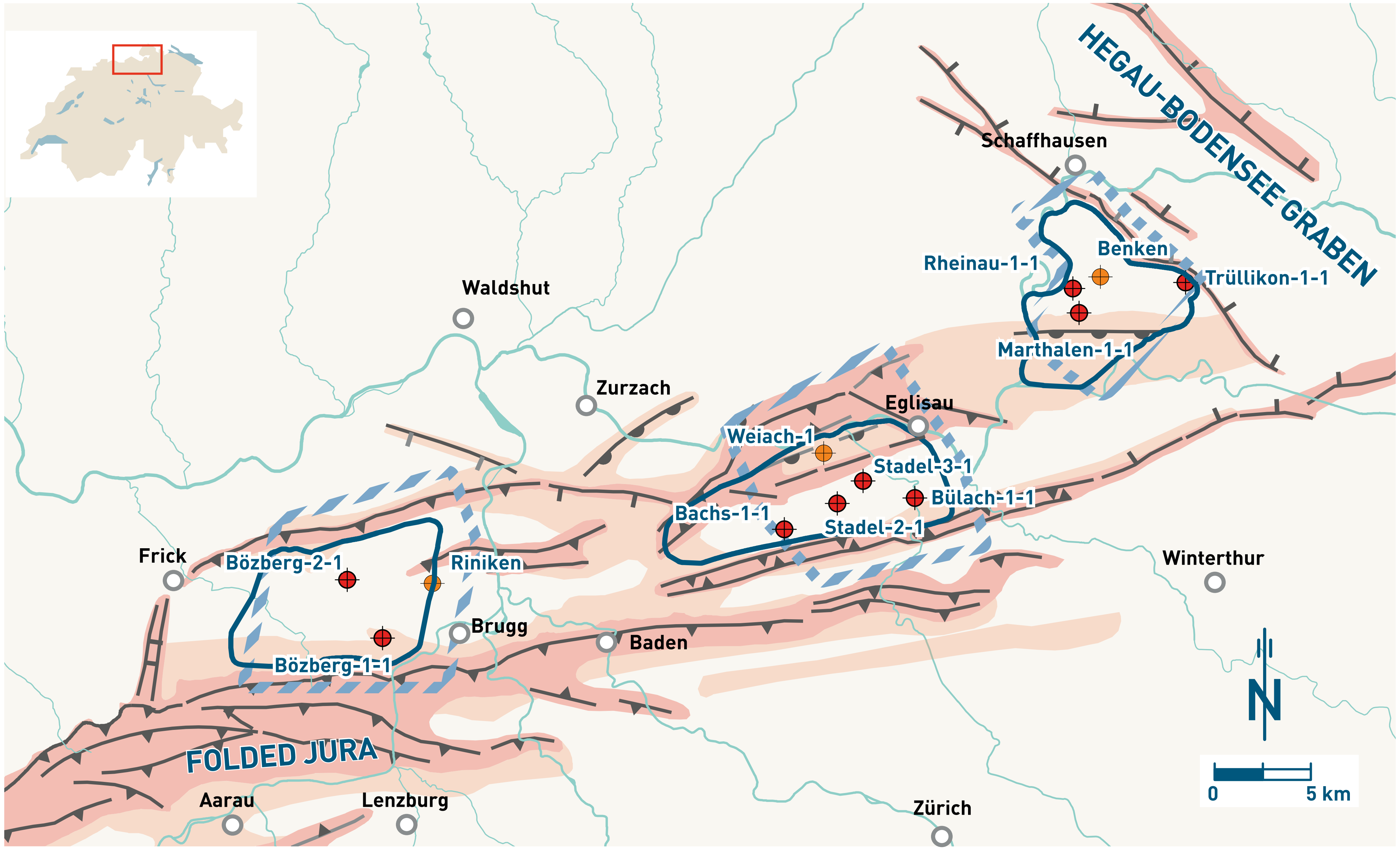
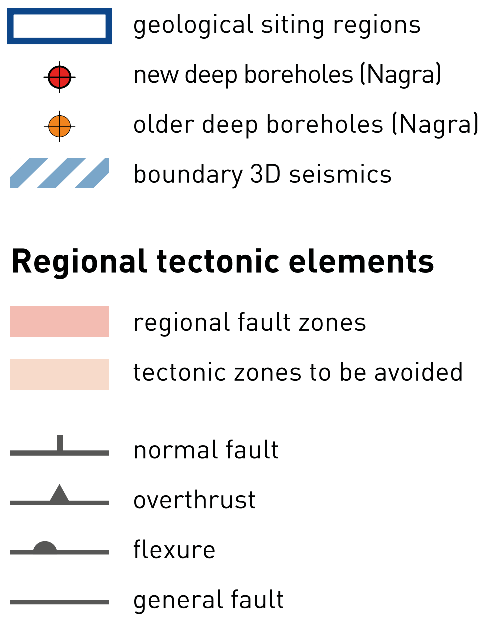
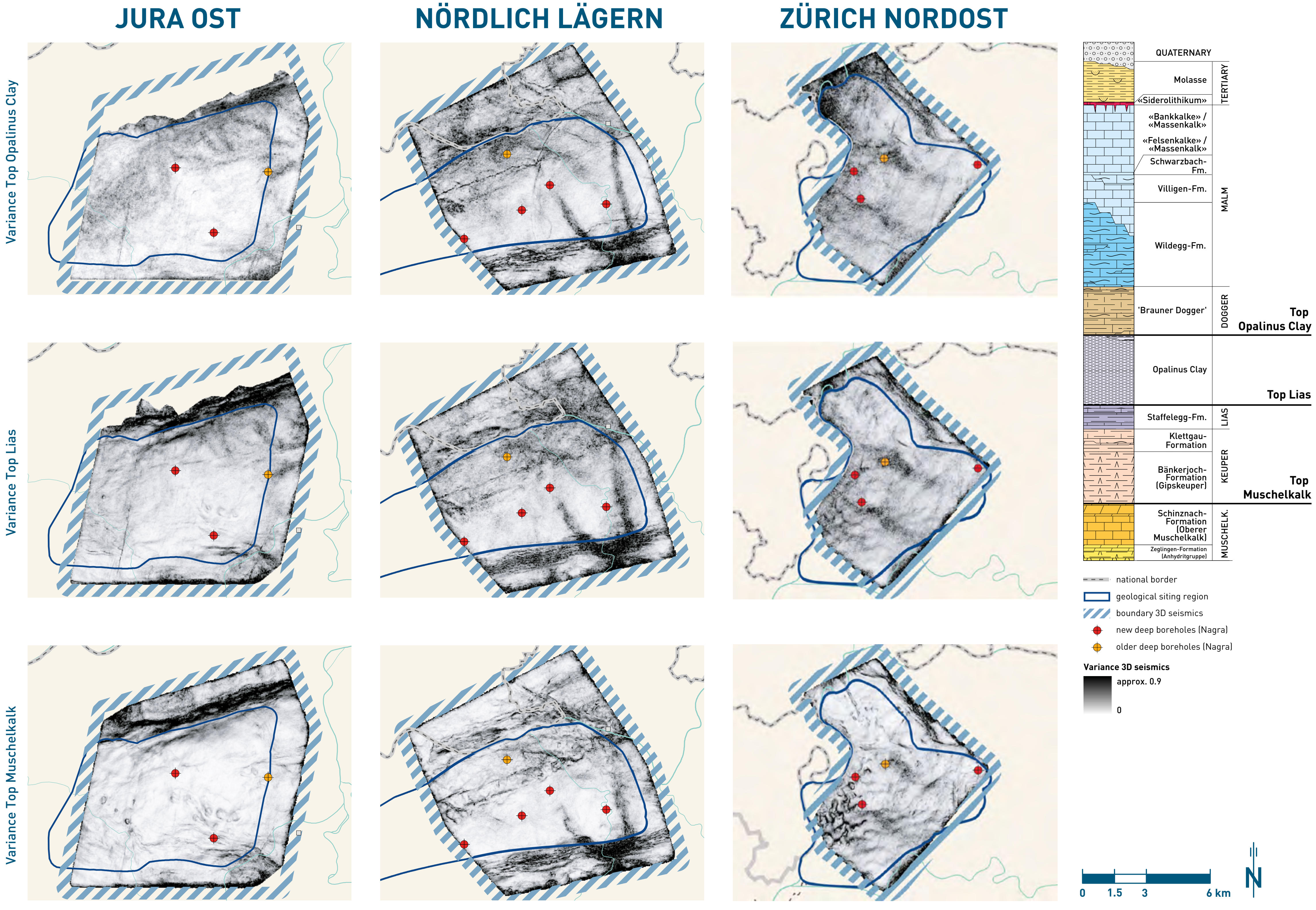


FIGURE 1: Overview map of Northern Switzerland showing regional tectonic elements (regional fault zones and tectonic zones to be avoided).

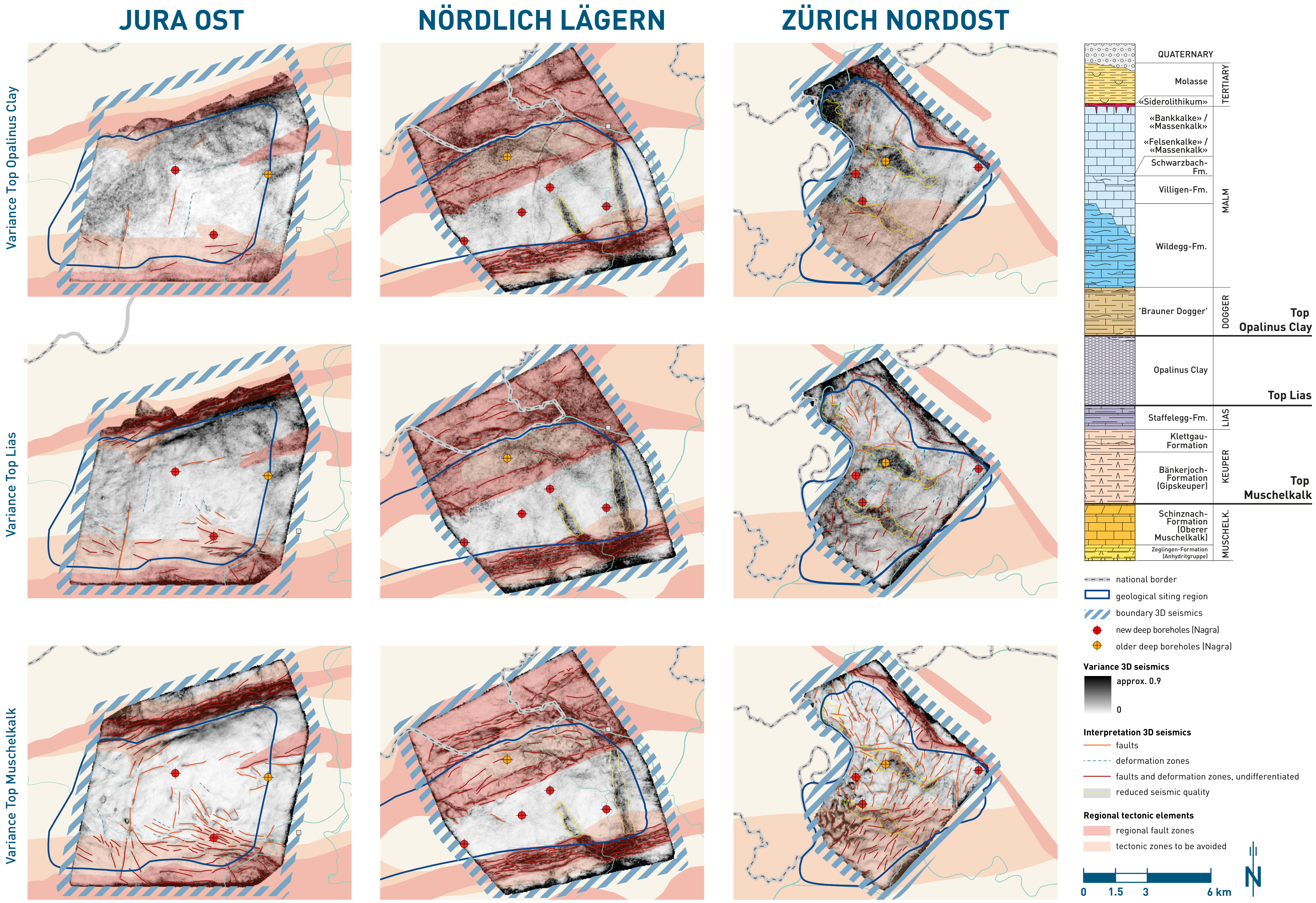


COMPARISON OF THE SITING REGIONS BASED ON 3D SEISMICS



3D seismic data are generally investigated and interpreted using different attributes. In this context, the continuity of geological layers is visualised with the seismic attribute "variance" to enhance discontinuity imaging. Figure 2 shows the variance maps of the three layer boundaries Top Opalinus Clay (top of the Opalinus Clay), Top Lias (bottom of the Opalinus Clay) and Top Muschelkalk (around 150 m below the bottom of the Opalinus Clay) for the three regions. Low variance values (light grey areas) indicate zones in the subsurface where neighbouring seismic data are very similar, i.e. the geological layers are very continuous. High variance values (dark grey areas) show where this is less the case, for example where the geological horizons are interrupted by tectonic faults. Areas where such typically linear zones are particularly pronounced frequently coincide with previously known regional fault zones (such as an ENE-WSW-trending zone at the southern edge of the NL siting region; cf. next page). In addition to tectonic causes, high variance values can also be attributed to reduced seismic imaging quality (e.g. two NNW-SSE-trending areas in the eastern half of NL; cf. next page).

FIGURE 2: Uninterpreted 3D seismic map of the siting regions for the marker horizons Top Opalinus Clay, Top Lias and Top Muschelkalk, here showing seismic variance.



In Figure 3, the variance maps are superimposed with the geological interpretation and show the trends of the interpreted tectonic structures. In central areas located outside regional tectonic elements, a distinction is made between faults (light red lines) and deformation zones (dashed blue lines). For the former, the seismic data directly indicate a fault. In the case of deformation zones, there is no direct evidence of faults on the corresponding horizon, but there are indications of small-scale deformation, for example in the area of folds or flexures situated above deeper-lying faults (cf. Figure 4 for concrete examples).

Some zones with increased variance values are associated with reduced data quality. This is particularly the case where elevated variance values coincide with the location of sediment-filled glacial troughs. The highly variable properties of these near-surface valley fills influence wave propagation and often have a negative impact on imaging quality. Such areas marked in yellow are not interpreted as faults, but they indicate increased uncertainties in the seismic mapping of the geological horizons and consequently also in the interpretation of the structural geology.

FIGURE 3: Interpreted 3D seismic maps of the JO, NL and ZNO siting regions for the three marker horizons Top Opalinus Clay, Top Lias and Top Muschelkalk.

EXAMPLES OF DIFFERENT TECTONIC STRUCTURE TYPES

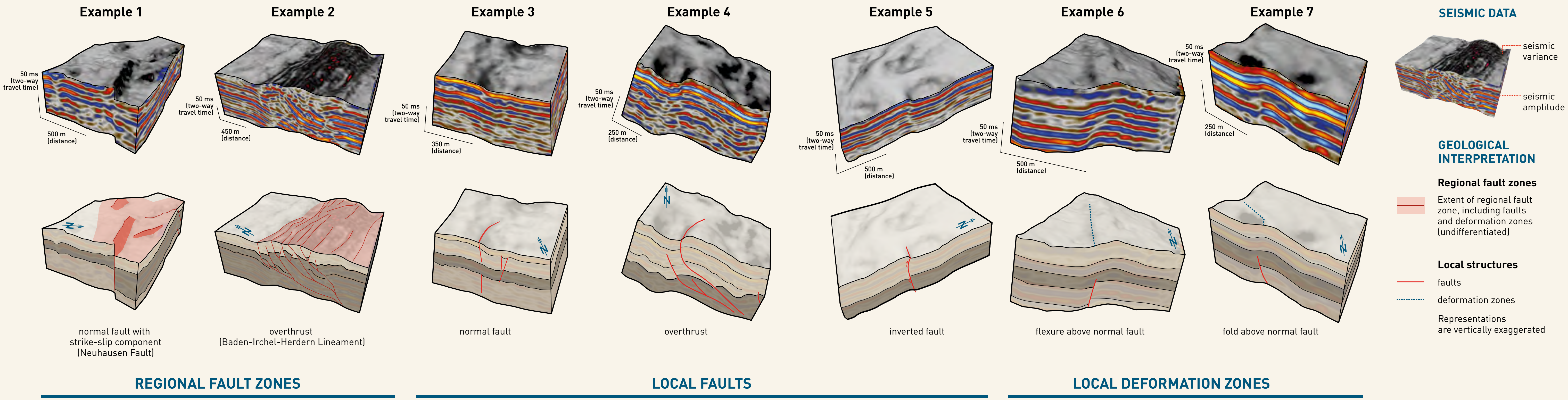


FIGURE 4: Examples of mapped geological structure types. The same excerpt from 3D seismics is shown without (above) and with (below) interpretation.

JURA OST

In Jura Ost, regional fault zones are found in the very south and in the north. Between these lies a zone with low variance values and correspondingly fewer faults and deformation zones. In particular at the level of the Top Muschelkalk, a structurally more complex zone extends northwards from the Folded Jura. At this level, the central area of the siting region is clearly more structured.

NÖRDLICH LÄGERN

In the north and south of the Nördlich Lägern siting region, zones with increased variance values and ENE-WSW-striking lineaments stand out. These are summarised as regional fault zones. Between these is a zone with very low variance values representing continuous, evenly bedded layers. In the east of this zone, two roughly NNW-SSE-oriented features with increased variance values are visible. These features coincide with glacial troughs, which impact seismic data quality and are responsible for the high variance values.

ZÜRICH NORDOST

In the Zürich Nordost siting region, a NW-SE-striking regional fault zone is present in the very north-east. In the south, an E-W-oriented zone constitutes a tectonic zone to be avoided. This zone was already identified in Stage 2 of the Sectoral Plan. It coincides with the reactivated northern margin of the Permo-Carboniferous Trough of Northern Switzerland (particularly well visible at the level of the Top Muschelkalk). In the central area, the variance values are mostly low, but there are some NNE-SSW-striking lineaments with increased variance values, which are interpreted as faults and deformation zones. Two wide NE-SW-striking zones with increased variance values coincide with sediment-filled glacial troughs and negatively impact data quality.

COMPARISON OF THE SITING REGIONS

At the level of the Opalinus Clay, all three siting regions have larger, tectonically quiet areas that lie at a distance to larger faults (i.e. those mapped with 3D seismics). The Nördlich Lägern siting region has the largest connected, tectonically quiet area. The differences between the siting regions are particularly visible at the level of the Top Muschelkalk located below the Opalinus Clay (Figure 3), but they are also evident in the overlying horizons.

Due to the structural geological situation with a large, continuous and evenly bedded central zone, the Nördlich Lägern siting region provides a comparatively large flexibility with regard to the layout of the repository. This finding is in line with the favourable tectonic location of the siting region with its distance to the Folded Jura and the Hegau-Bodensee Graben.

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Nagra | National Cooperative
for the Disposal of Radioactive Waste
Hardstrasse 73 | 5430 Wettingen | Switzerland
T. +41 56 437 11 11 | info@nagra.ch | nagra.ch