TGK hydrocarbon exploration in Central Switzerland : experience with alpine reflection seismics

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TGK Hydrocarbon Exploration in Central Switzerland: Experience with Alpine Reflection Seismics

by
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with 5 figs.

Zusammenfassung

In diesem Artikel werden die Organisation sowie das Explorationsprogramm des TGK kurz beschrieben. Auf die reflexionsseismischen Feldarbeiten und einige Aspekte der Daten verarbeitung wird speziell eingegangen. Erste Resultate von allgemeinem Interesse werden dargelegt.

Resumé

Cet article donne un aperçu de l'organisation et du programme d'exploration du TGK. Les travaux de sismique réflexion, quelques aspects du traitement de données ainsi que les premiers résultats d'intérêt général sont ici présentés.

Abstract

This paper gives a summary of TGK's organisation and exploration activities. Reflection seismic acquisition and processing techniques are discussed and first results of general interest are presented.

1. TGK Organisation

In 1987 Swisspetrol Holding Ltd. of Zürich and Sulzer Brothers Ltd. of Winterthur established on equal terms the Tiefengas Konsortium (TGK). While for Swisspetrol the exploration and production of hydrocarbons in Switzerland is the actual objective, Sulzer's main interest as a technology corporation lay at that time in a potential diversification in the natural gas business.
Since 1989 the Swiss «National Energy Research Fundation» (NEFF) contributed substantially to the exploration budget of TGK in view of the research aspects of the project.

The TGK group (Fig.1) consists of a core team of two earth-scientists. TGK also draws on the expertise of external professionals from the consulting and the oil and gas industry and sub-contracts to specialized companies and institutes. A Scientific Advisory Board, consisting of reputed experts, has been set up to monitor and advise on results.

1) TGK TIEFENGAS KONSORTIUM SWISSPETROL/SULZER, CH-6010 Kriens

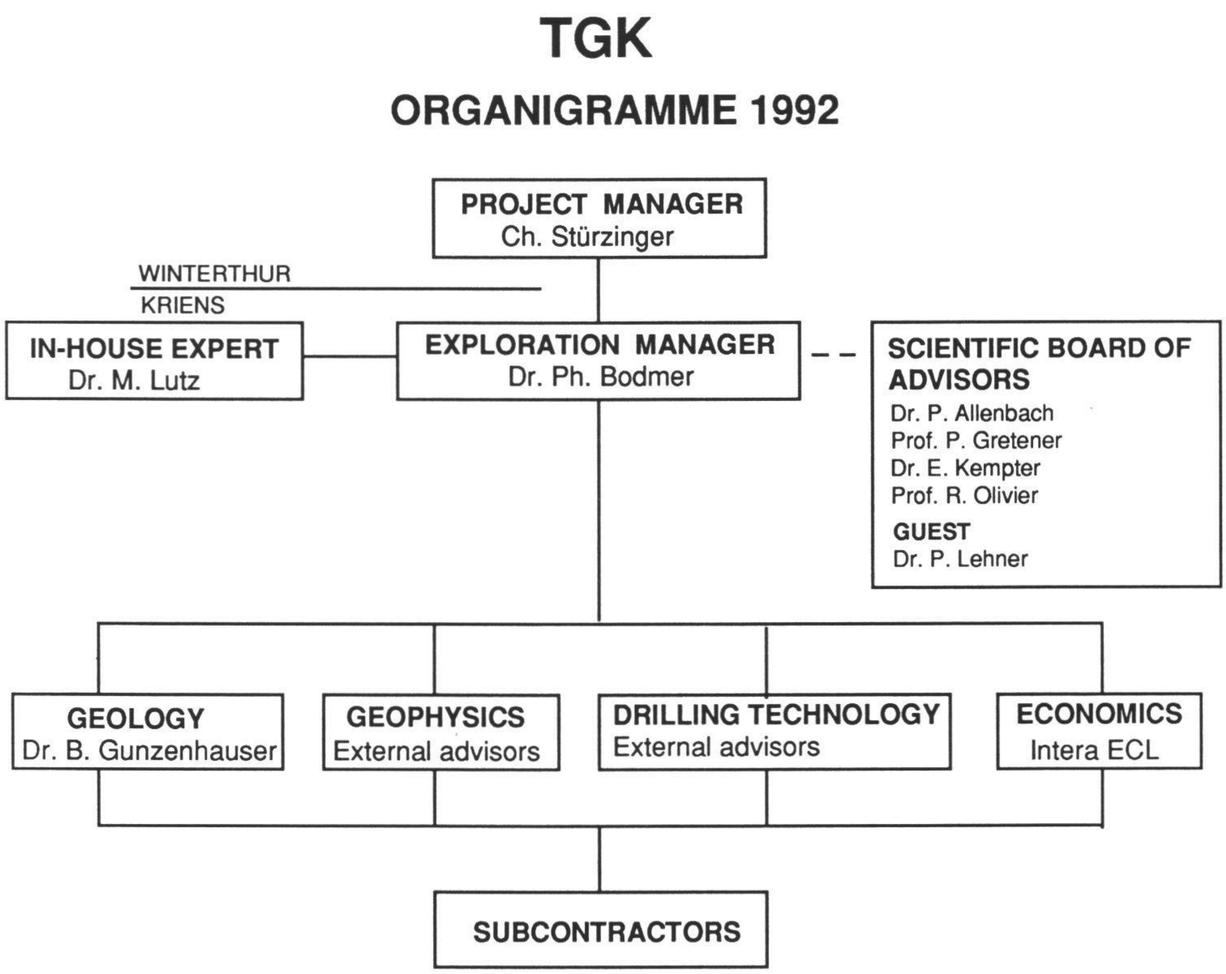

Fig. 1 TGK Organigramme 1992.

From the history of hydrocarbon exploration and drilling campaigns in Switzerland a number of conclusions (well known to the trade) can be drawn:

— Switzerland is under-explored in terms of seismic data and drillholes.

— The presence of hydrocarbons (mainly gas) is not critical to exploration, as gas production in the Entlebuch-1 well, uncommercial discoveries in exploration wells and many shows as well as surface indications and seepages have shown.

— Traps apparently are present in a number of plays, although the validity of older tests has to be questionned (no seismic data or bad quality of older vintages).

— Lack of reservoir development (porosity and permeability) has probably been the detrimental factor in the exploration for hydrocarbons.

With these points in mind, TGK has developed a novel theoretical model of trap and reservoir formation which could now be tested by drilling an exploration well for which TGK will be seeking a partner.

2. Exploration Activities

In 1989 TGK obtained exploration permits (»Schürfkonzession») in the cantons Obwalden and Nidwalden and the northern part of Uri (total area 1195 km²). During the last four years a series of geophysical and geochemical field surveys were carried out on behalf of TGK.

Geochemical investigations of soil samples, gas samples from seepages and a large gas detecting survey have shown that:

- The outgassing (mainly methane) in the region of the Helvetic nappes is concentrated near major faults.
- Isotopic analyses of $\delta^{13}C$ and δD clearly characterize the gases to be thermogenetic.

Fluid inclusion studies, carried out by J. Mullis, University of Basel, from gas bubbles (mainly methane) in quartz and calcite veins in the different tectonic units allow the reconstruction of p-T conditions during the time of inclusion (10-15 my bp).

Geophysical surveys include a large gravity survey and the acquisition of 205 km of reflection seismic data. Mainly in the northern part of Obwalden and Nidwalden, 9 vibroseis lines were shot between 1976 and 1978 by Prakla Seismos AG on behalf of LEAG/BEB (Fig. 2). These lines were received by TGK as part of an exchange agreement and were reprocessed in 1989.

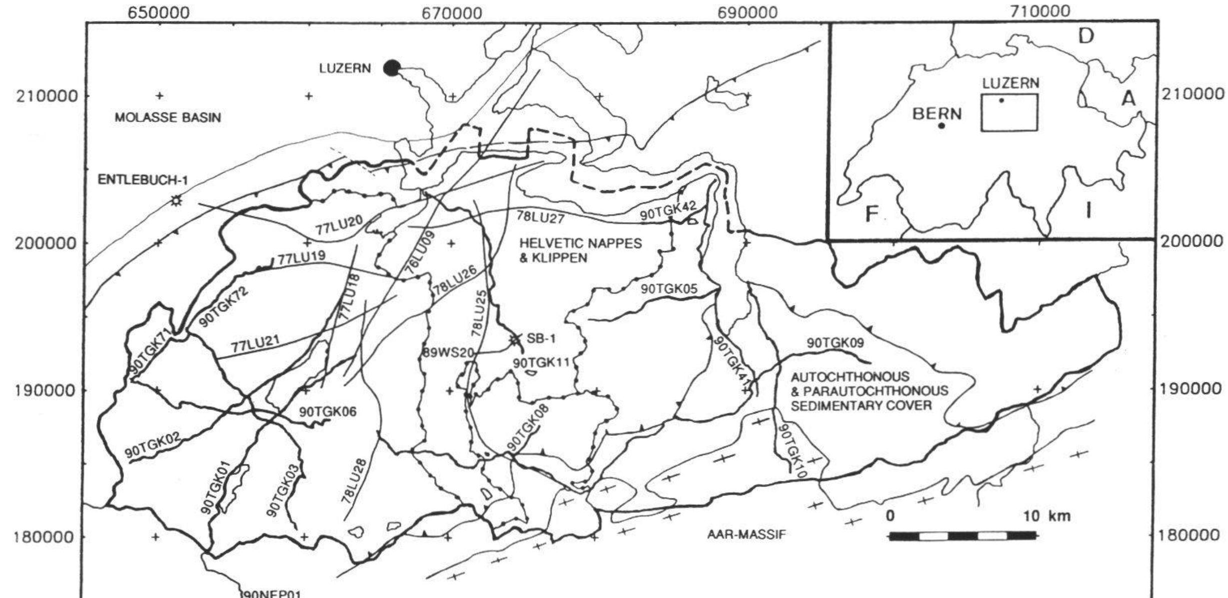

Fig. 2 TGK Concessions and seismic location map, Central Switzerland

Based on the prerequisites of the TGK model, the regional hydrocarbon geology of the area and the nearby production of natural gas in Entlebuch-1 to the west of the exploration permit, the main exploration target is the sedimentary sequence below the Helvetic nappes.

Regional studies of available subsurface and outcrop data were carried out in order to assess potential reservoir zones within the target section. Feasability studies of the technical and economic aspects of (an) exploration well(s) are rounding off TGK's activities.

3. TGK Reflection Seismic Survey 1990

3.1 *Acquisition*

During the summer of 1990 eleven lines with a total length of 205 km were acquired by Prakla Seismos. Vibroseis™ sources were used along roads accessible for the vibrators; on three lines with rugged terrain explosive sources in shotholes were applied. The shotholes were drilled by heli-portable drilling units of Prakla Seismos and by drilling equipment mounted on a small caterpillar-like vehicle (Fehlmann Grundwasserbauten AG).

The layout of the lines was planned to achieve best possible coverage of the area (according to accessability and budget considerations), maximum tie-points to the previous LEAG survey and a dip and strike alignement to structural elements. Topographically the strike lines run along very rugged terrain with altitude differences of up to 1800 m (i.e. line 90TGK09, Surenen-Pass 2291 m).

Outside the main valleys the lines are «slaloming», whereby the CDP distribution becomes very scattered. The geophone lines were placed as close as possible to the vibrating lines. This enabled an efficient installation and removal of the recording layout. Minimum offsets between the receivers and sources allowed more accurate refraction investigations (see chapt.3.2) to determine the static corrections. The effect of CDP scattering was successfully used in processing to investigate lateral dips and produce locally mini-3D coverage/areas.

Acquisition parameters:

Number of channels (nominal)	144 — 172
Geophone group spacing	50 m
Configuration	generally symmetric split-spreads
Vibration point spacing	50 m
Vibrators	5
Sweep	11-61 Hz, linear, 20 s
	2 sweeps / position, vert. stacking 4 fold
Coverage (nominal)	72 — 84 fold
Shot point spacing	100 m
Shothole depth	7 — 8 m
Shot / shothole position	1
Charge	2 — 5 kg
Recording:	
number of geophones per group	24
pattern	1 row, in line; 48,3 m
rec. length	6 s
sampling rate	4 ms

In cooperation with NFP 20 (an independent seismic research project on the deep structure of Switzerland, which is funded by the «Swiss National Science Foundation») the line 90TGK01 was continued in the same operation, but under NFP 20 auspices, into the line 90-NF-01, which runs from the Brünig Pass for 22 km in a southeasterly direction towards the Grimsel Pass. Hereby full coverage at the meeting points of the lines and reduced costs were achieved.

3.2 *Processing, Static and Dynamic Corrections*

The reflection seismic profiles were processed by the Companie Générale de Géophysique (CGG, Massy France). A close collaboration between the processing center and TGK, however, was necessary to take best advantage of the local geologic knowledge.

This was particularly important during the phases of static and dynamic (NMO) corrections of the seismic data and special emphasis was put on these two aspects in the following paragraph.

For each vibration or shot, a single-shot record was plotted in the field. A manual first-break analysis of these records allowed the determination of line sections being affected by weathering or thick Quaternary sediments. A quick manual refraction interpretation was done by TGK prior to a more precise evaluation by CGG using GARDNER's method (LAYAT, 1967). Within the valleys, where the Quaternary fill sometimes exceeds 300 m, the refraction results were checked using the more accurate refraction modelling technique proposed by SCOTT (1973).

The shape of the bedrock below thick Quaternary sediments could usually be determined by interpreting short constant velocity stacks of one second TWT, using velocities in the range of 1800 — 3100 m/s and the near traces only. Figure 3 represents a preliminary Quaternary basin model based on refraction data, which was later used for detailled refraction modelling.

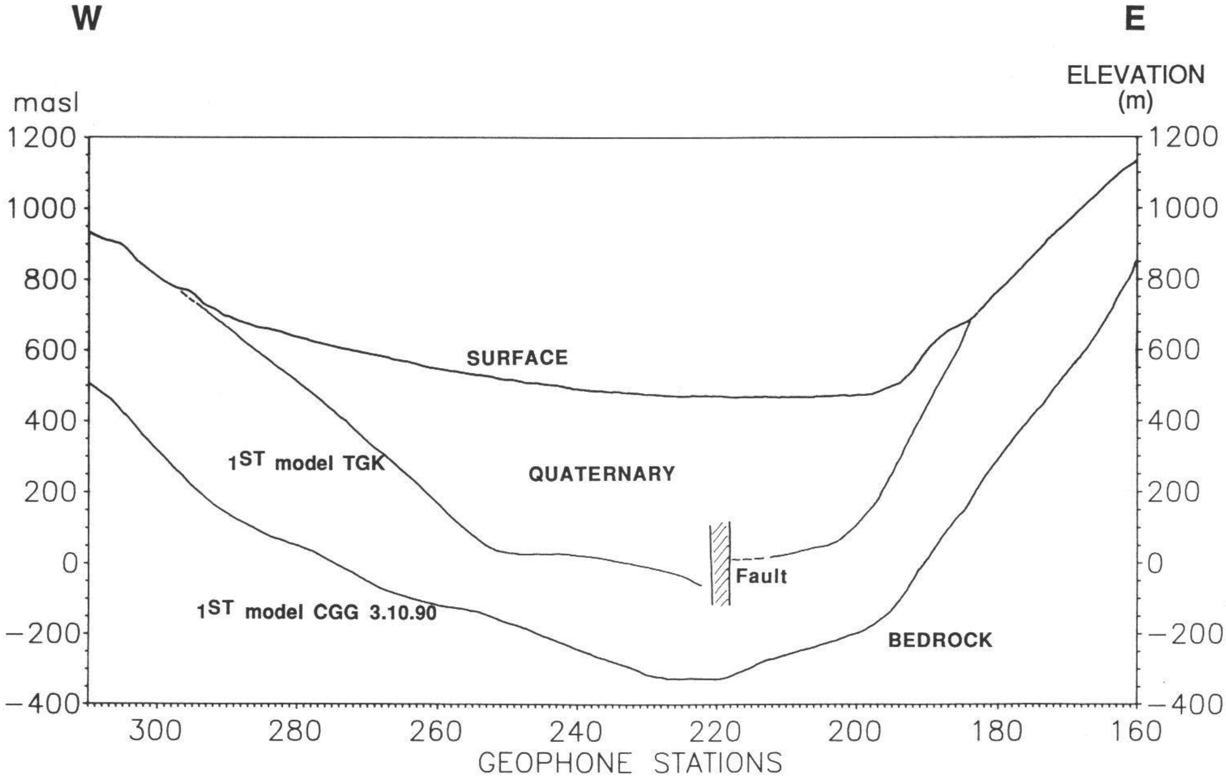

Fig. 3 Models of Quaternary basin according to refraction seismics

The large discrepancy between the two models is explained as follows: In the first model, unfortunately, the average intercept curve was calibrated at the flanks of the basin, having a velocity of 3500 m/s. In the second interpretation, however, the calibration was done within the central part of the basin using realistic velocity values of the weathering zone ranging between 2000 and 2500 m/s. The results based on the second model were more in accordance with the reflection results from specific velocity scans and with the SCOTT interpretation. Based on the experience of previous seismic sur-

veys in the Alps, velocity measurements in uphole wells, which did not reach the depth of the bedrock, are considered inefficient.
In order to assess static corrections, reflection and refraction techniques were applied. These two are complementary, depending on the acoustic contrasts present at depth. The reflection technique is more favourable to sharp seismic impedance contrasts including density variations, i.e. between unconsolidated sediments and the bedrock. In this situation the seismic response is of the DIRAC type, containing a broad frequency spectrum, thus characterizing a good seismic reflection. Outside the Quaternary basins the weathering of the bedrock gradually decreases with depth and hence a progressive velocity increase with depth is observed. The seismic response of such a situation could be modelled by the convolution of a time succession of small DIRAC signals. The result of this, is a low frequence response which is more characteristic to high - angle reflections or to refractions. In addition to that, seismic signals running through a medium of increasing velocity at inclined incidence angles, will tend to be refracted successively along the different dioptres, and will, therefore, be deviated into the direction of the layering.

Since near-surface reflection data do not provide sufficiently reliable information on Quaternary depth we recommend for future seismic campaigns to use vertical seismic profiling (VSP) techniques in 100 m deep wells with, for instance, 5 m receiver spacing in the hole. In this way better results for static corrections are expected. The VSP measurements could be done simultaneously with the reflection seismic acquisition using one vibrator at the surface (i.e. 10 m spacing between the individual emissions) and a multi — receiver tool in the well. An alternative might be to install the receivers at surface and to detonate small charges at varying depth intervals in the hole. Using the surface seismic data in conjunction with the emissions within the well an accurate (i.e. 20 fold) stack of the Quaternary basis could be constructed. The disadvantages during field operations in respect to time and budget are obvious.

The dynamic corrections were based on the interpretation of velocity scans and on velocity analyses (VELCOM,™ of CGG) spaced at 2.5 km intervals. Since optimum

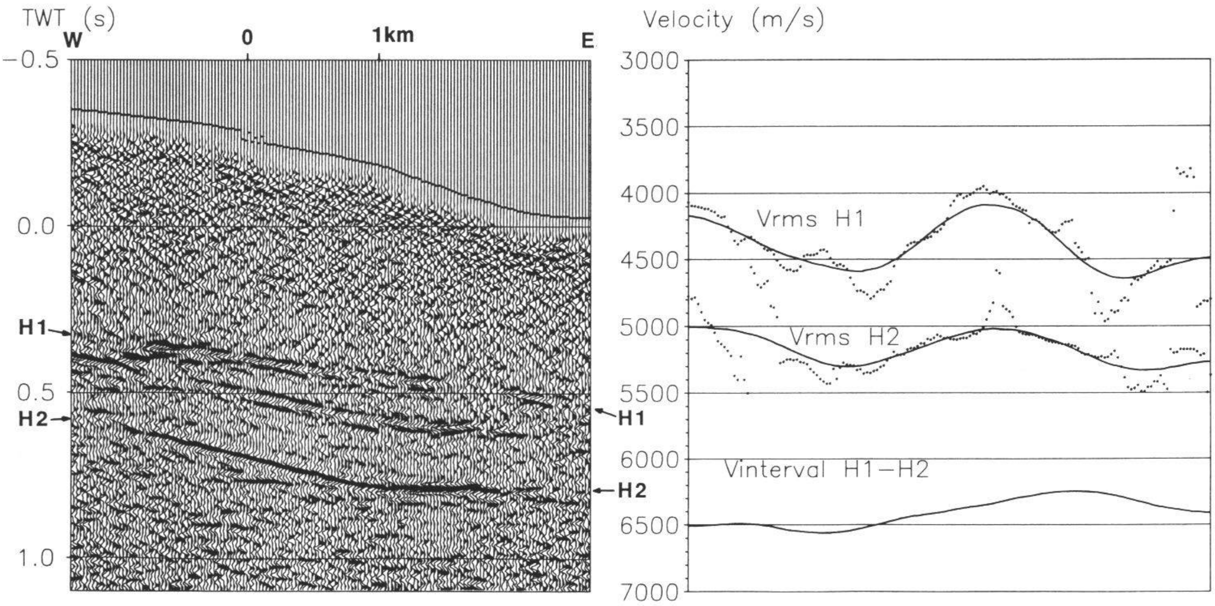

Fig. 4 Time section, velocity horizons and interval velocities across the Helvetic nappes

stack velocities do not always provide geologically significant data, velocity horizons were processed along the major regional reflectors, in order to assess the spacial distribution of interval velocities. Velocity horizons computed down to about the first second (Helvetic nappes) usually provided reliable results as shown in figure 4. In this example interval velocities are very high, ranging between 6300 - 6500 m/s. Taking the dip of the reflection and possible anisotropy into account, geologically reasonable velocity values for this 900 m thick sequence between the two reflections can be deducted.

4. Results

The quality of the 1990 seismic data is generally good, inspite of the complex alpine tectonics. The autochthonous Mesozoic sequence is clearly visible as a band of strong reflections. The overall change in thickness of the Mesozoic from Entlebuch-1 to the outcrops of the Aar Massif autochthonous cover can not be detected on seismic data. This suggests that this change occurs more internally, below the northern front of the Aar Massif. Generally the Mesozoic is disected by normal faults (trends are difficult to establish), but in the frontal part of the massif it is affected by thrust tectonics.

The northern front of the Aar Massif in the subsurface reaches a line running approximately from Giswil to Flüelen. A stack of imbricated thrust-slices of basement and Mesozoic characterizes the front, which overrides the southward dipping autochthonous sediments, which can be traced almost as far as Innertkirchen (Fig.5). The depth of the synclinal form of Helvetic and higher nappes leaves some 4000 m of thrust duplicated Molasse (Lower Marine Molasse?) and internally North-Helvetic Flysch, sandwiched between the nappes and the autochthonous Mesozoic. Seismic data indicate, that deep-reaching fault systems underlie the valleys of Sarnen and Reuss.

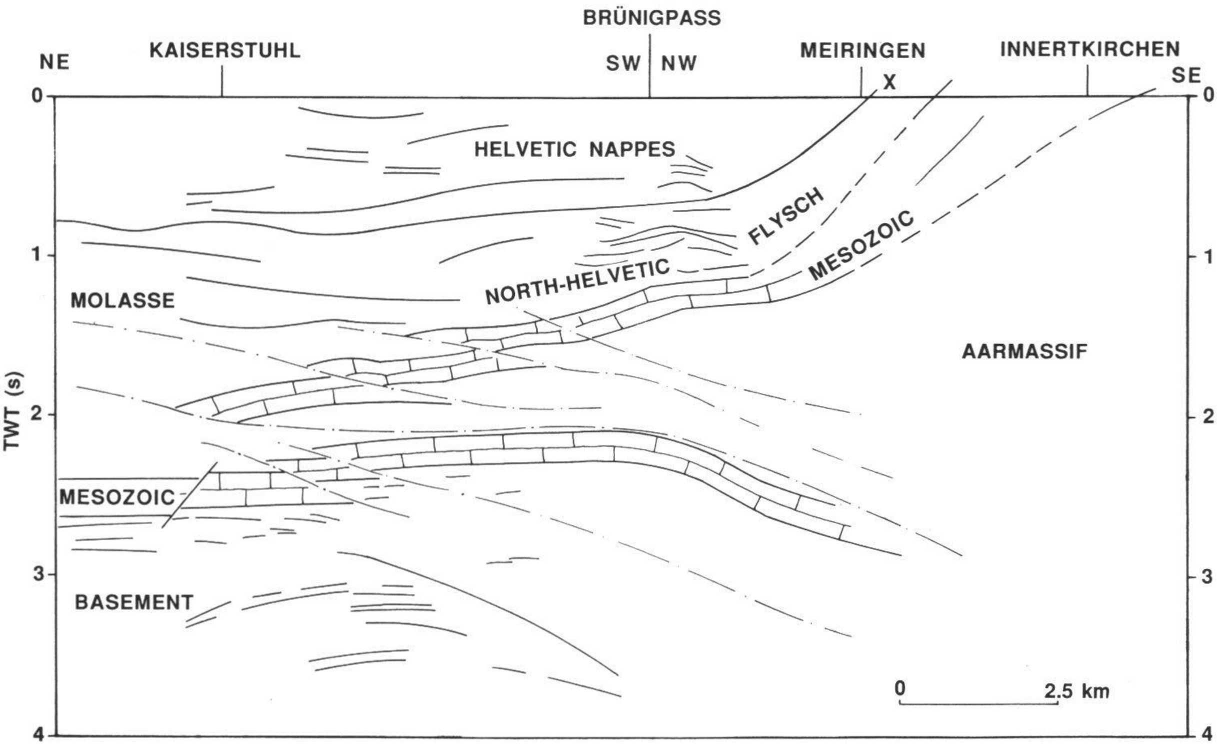

Fig. 5 Geologic sketch of the northern front of the Aar Massif

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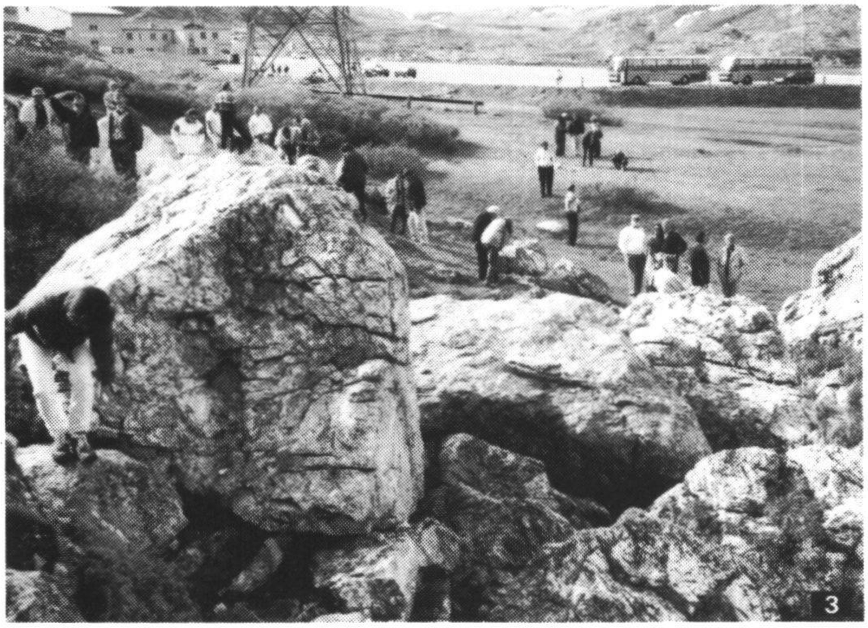
Jahresversammlung 1992 - Bilder von den Exkursionen



3. Curtinatsch. Die Piz Alv - Breckzie kann in Bergsturzblöcken studiert werden

4. Der gewaltige Bergsturz von 1985 im Veltlin vom Gegenhang gesehen