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Swiss oil/gas exploration and lessons learnt

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1. Introduction

The search for domestic oil and gas resources in Switzerland started almost exactly one hundred years ago, in parallel to similar activities in neighbouring countries in Central Europe. It was only after the Second World War that large scale consumption of imported hydrocarbons started. Despite the absence of commercial oil or gas discoveries in Switzerland, over less than 20 years imported oil became the main energy source for car fuel and heating purposes. Since 1970 the energy share of oil and gas steadily increased, representing today 68% of the total Swiss energy consumption. This strong dependency on foreign fossil energy sources, in a time where the future energy supply scenarios for a post-nuclear and CO_2-neutral era are discussed, represents an additional challenge. Indigenous fossil energy, especially gas, may play a key role in this energy transition phase. The objective of this short review is to analyze the possible geological reasons for the disappointing exploration results to date, to summarize the current activities and to sketch an outlook for future exploration.

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Summary of a presentation given at the VSP/ASP annual convention 2011 in Yverdon-les-Bains, Switzerland.

2. 100 years of exploration: What has been found?

During the last hundred years 37 deep wells have been drilled in the search for domestic oil and gas resources in Switzerland (Fig. 1). The majority of these exploration wells aimed at conventional targets in the Tertiary to Paleozoic section of the Foreland Basin north of the Alps. Exploration emphasis shifted with time from oil in the Tertiary to oil/gas in the Mesozoic and to gas in the Mesozoic and Permo-Carboniferous (Fig. 2).
Despite the numerous good oil and gas indications (see below) only one semi-commercial gas field went into production (Entlebuch-1, 5'289 m, Carboniferous at TD, cumulative production from carstified upper Jurassic limestones of 2.65 bcf or 74 Mio. m^3).

Over 800 reflection seismic lines with a total length of ~12'000 km were acquired between 1954 and 1990 by the petroleum industry (Fig. 1). The first seismic data of Switzerland was probably acquired in the Concise area north of Lake Neuchatel in 1928 (Weidmann 1991). However, it was only after 1960 that reflection seismic data was used on a routinely basis in the process of planning deep wells.
Until 1950 the exploration in Switzerland was mainly characterized by small ventures of private independent petroleum companies (Fig. 2). During this phase drilling targets were chosen based on surface seeps, surface geology and in some cases following

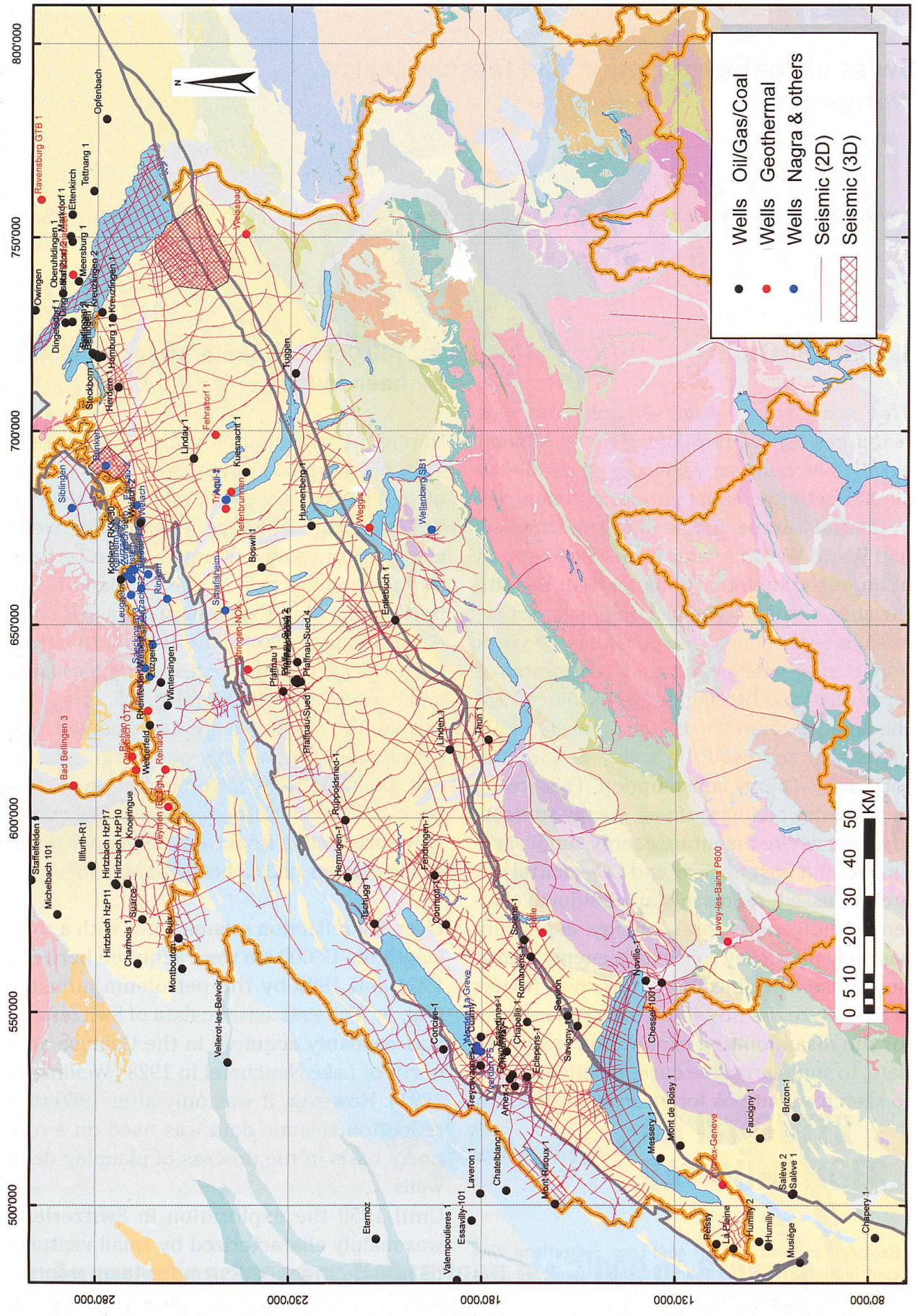

Fig. 1: Tectonic map of Switzerland and adjoining areas (courtesy Swisstopo) with 2D and 3D seismic data and deep wells.

hints of geomantic specialists. In 1934 the Société Anonyme des Hydrocarbures (SadH) was founded to explore a large permit in the Canton de Vaud of Western Switzerland. Modern exploration started in 1956 when, as a result of the Suez crises, the Swisspetrol Group was established that bundled the activities of over ten local Swiss companies and two major foreign petroleum companies (BEB-Shell-Exxon and ELF Aquitaine, Lahusen & Wyss 1995). It was under the Swisspetrol Group that until 1989 (Thun-1) over 27 deep wells were drilled, however, with the exception of well Entlebuch-1, without economic success.

Related to the fact that a total exploration expenditure of over 350 Mio. CHF showed only disappointing results, all foreign joint venture partners withdrew from Switzerland and the former Swisspetrol Group was dissolved in 1993. Only SEAG (Schweizerische Erdöl AG) in eastern Switzerland and Petrosvibri SA in Vevey remained after this restructuration. From 1995 to 2005 the exploration activity continued at a very low level, with only one dry well drilled in a joint venture by Forest Oil / Ascent Resources / SEAG in 2000 (Weiach-2, 2'010 m, Carboniferous at TD). Weiach-2 tested a basin centered gas play at the edge of the Permo-Carboniferous graben structure of Northern Switzerland, extending from Lake Constance westward. The well followed promising gas indications of a nearby scientific well (Weiach, Nagra), which demonstrated for the first time the existence and sedimentary fill of Paleozoic troughs below the Molasse Basin. At the same time several American companies investigated the CBM potential of Carboniferous coals (> 1'500 m depth) in these Paleozoic troughs.

3. Numerous hydrocarbon shows

Oil and gas shows at surface, in tunnels and in wells are numerous in Switzerland north of the Alps and encouraged since at least one and a half centuries the exploration for exploitable subsurface accumulations (Weidmann 1991). In the beginning mainly oil

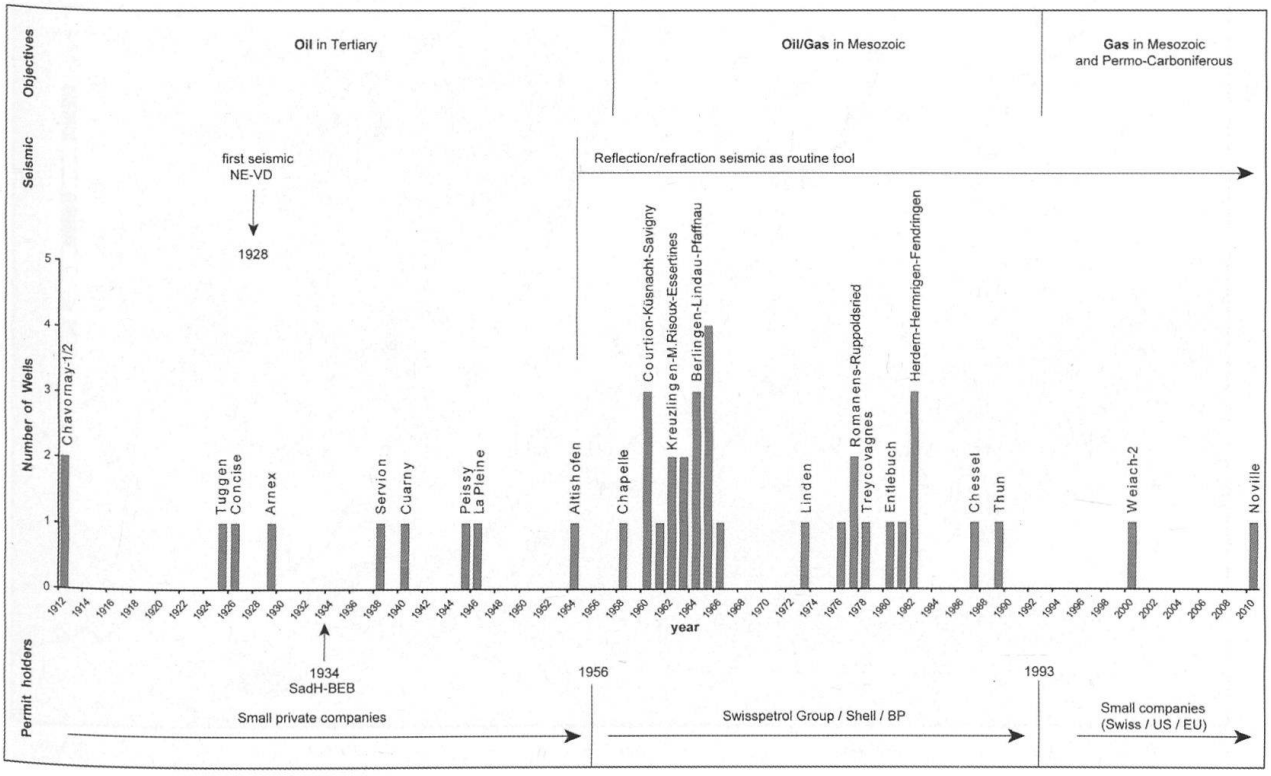

Fig. 2: Swiss history of deep drilling activity from 1912 to 2010 with its geological objectives and main permit holders.

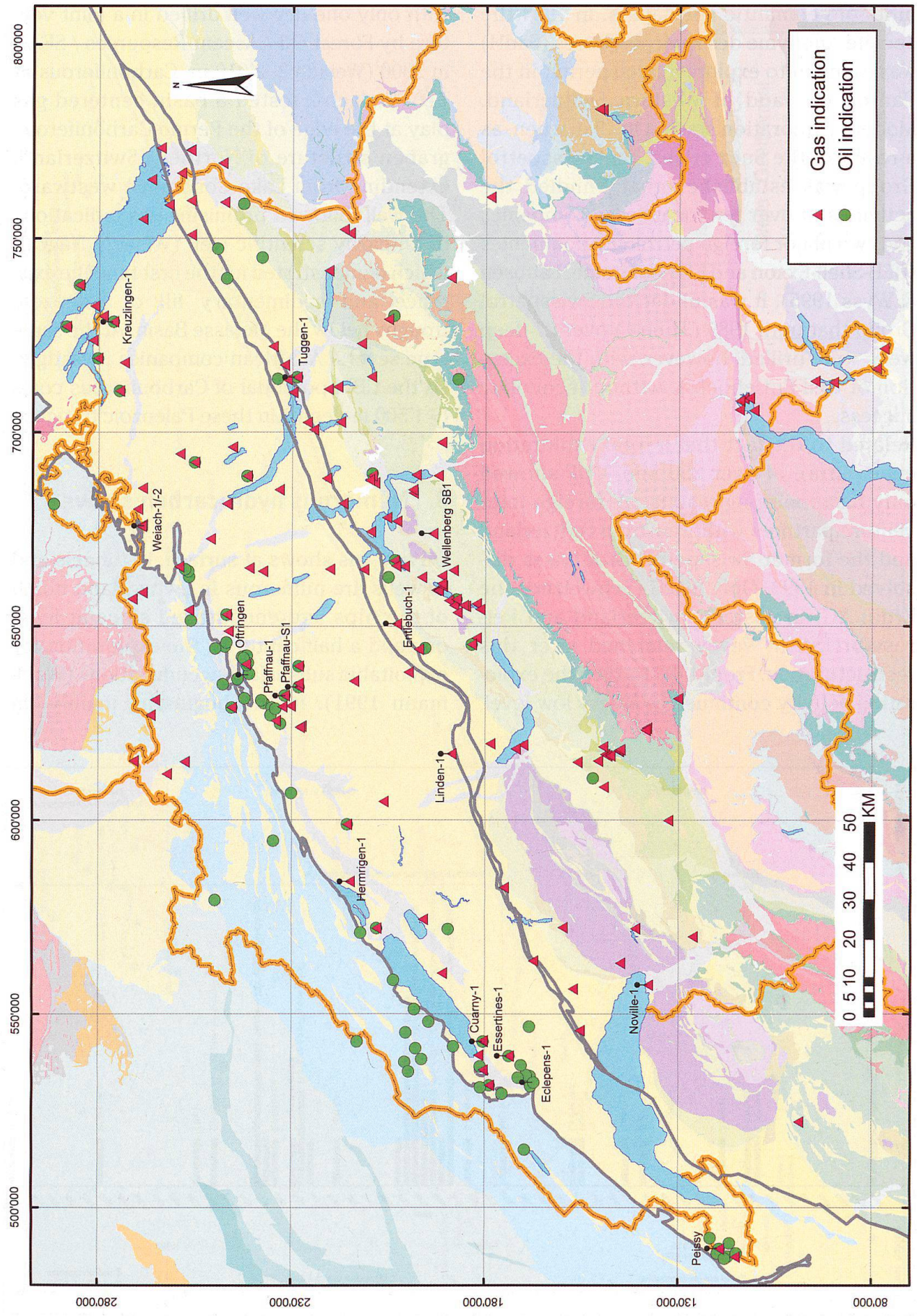

Fig. 3: Tectonic map of Switzerland and adjoining areas (courtesy Swisstopo) with known gas and oil indications at surface, in tunnels and deep wells (modified from Leu 2008).

seeps attracted the attention of explorationists (e. g. Molasse around Geneva, Eclepens-Yverdon or Aarau-Oftringen area). It was only during the last thirty years that also the distribution and geochemistry of the many gas seeps was studied in detail (Büchi & Amberg 1983, Greber et al. 1995 or Sachs & Eberhard 2010).

Surface oil seeps (Fig. 3, Leu 2008, Nagra 2008) occur at a high density within a narrow belt extending from Geneva over the Yverdon area to Baden along the distal edge of the Molasse Basin, in the western Jura Mountains and within the subalpine Tertiary triangle zone east of Lake Thun. Schegg et al. (1999) demonstrated with basin models in

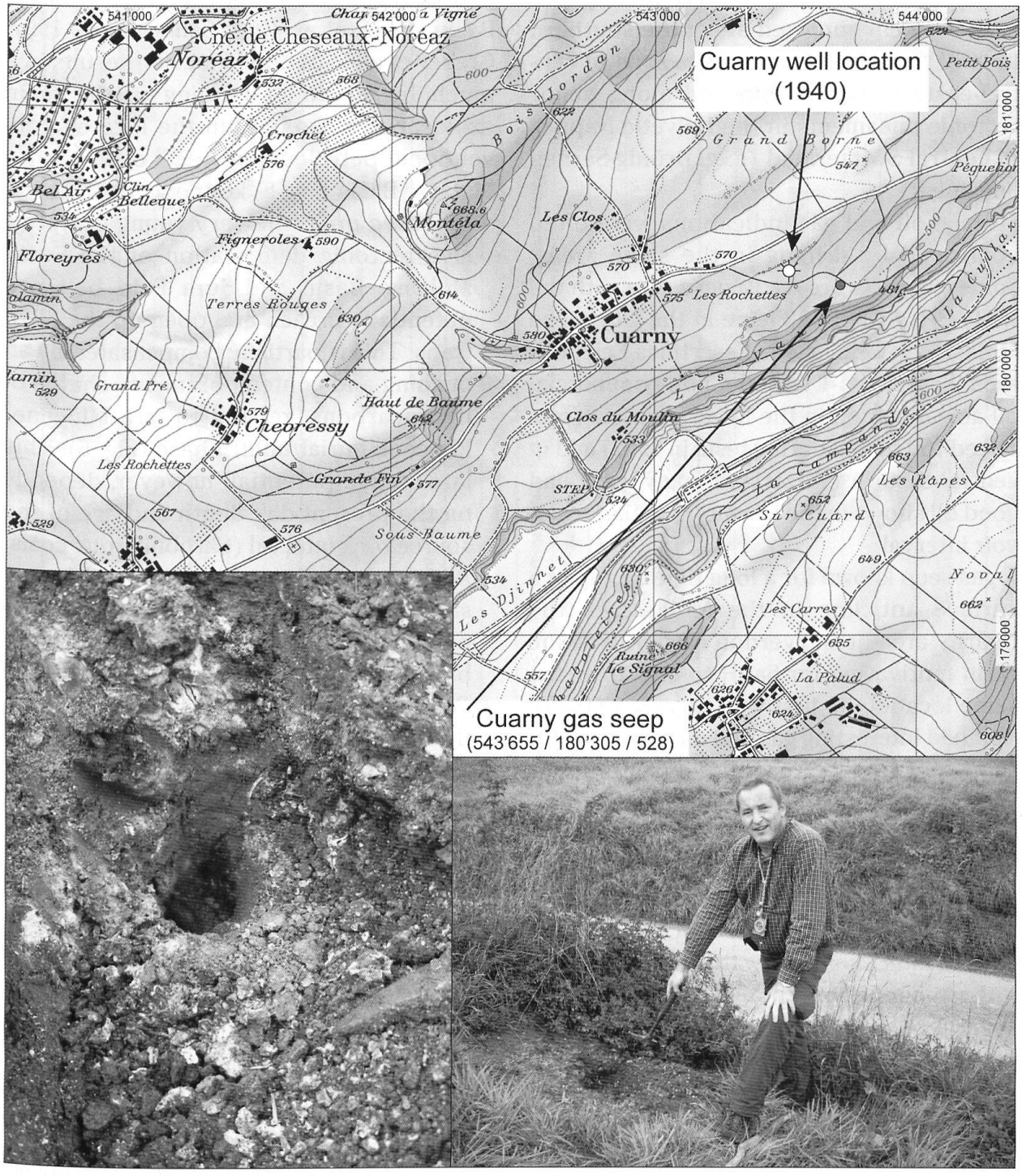

Fig. 4: Topographic map of Cuarny area with well Cuarny-1 and gas seep. Photos: Bernhard Gunzenhauser exposing the soil and demonstrating the burning gas seep (photo courtesy E. Dolivo).

western Switzerland, that this distribution is a function of lateral migration in the Mesozoic sedimentary stack, the maturity distribution of the potential oil prone source rocks (Autunian shales, Toarcian shale, Rupelian shales) and the location of deep reaching fault zones. Known gas seeps are more regularly distributed across the Molasse Basin with a slightly higher density towards Lake Constance. Frequently gas seeps are encountered along the southern limb of the subalpine triangle zone of central-eastern Switzerland and along major tectonic lineaments in the Helvetic Nappes of central Switzerland (e. g. Brünig-Sarnen lineament).

Surface oil and gas indications were often confirmed by drilling in the same areas. Some examples are the Geneva area with the wells Peissy and La Pleine in the Oligocene Molasse or wells in the Essertines-Eclepens area. Essertines-1 tested a non-commercial oil accumulation in the lower Jurassic (produced 150 bbl oil during tests in 1963) and in central-eastern Switzerland many wells had good oil shows in the Liassic/Rheatian reservoir interval.

A gas seep known for a long time on top of a surface anticline in the Molasse of the Cuarny area near Yverdon (Fig. 4) was the main motivation for SadH to drill near the same location its first well Cuarny-1 (1940), that had interesting gas and oil shows in Tertiary and Dogger reservoir layers. Other wells with promising gas shows were later drilled in Pfaffnau-Süd (Lower Freshwater Molasse, Lahusen & Wyss 1995), Linden (Lias and Malm) and Hermrigen (gas in Muschelkalk and Dogger). Geochemical data of such indications show that the gases have a thermogenic origin and originated from several potential source rocks (Carboniferous, Mesozoic and Tertiary). They are often mixed with bacterial shallow gases (Greber at al. 1995, Lahusen & Wyss 1995).

4. Petroleum systems and risk factors

The geological and tectonic framework of the Molasse Basin and adjoining Jura fold belt has recently been reviewed on a large scale including more industry seismic and well data (Sommaruga et al. 2011, Nagra 2008). Detailed analysis of the conventional hydrocarbon habitat of the Swiss Molasse Basin (Brink et al. 1992, Schegg et al. 1997, Greber et al. 2004 and Leu 2008) results in a much better understanding of the main exploration risks. Within the located conventional petroleum systems of the Swiss Molasse Basin (Fig. 5) key concerns are:

- *Breached traps*: the very young compressive tectonic deformation of the Swiss Molasse Basin and Jura Fold belt can potentially breach and open up the filled traps. This is partially compensated by an ongoing and contemporaneous charge of hydrocarbons, related to late Miocene/Pliocene burial/uplift phase (Fig. 6). This late charge potential, however, depends on the present-day depth and age of the source rock interval (Carboniferous coals, Autunian shales, Posidonian/Aalenian shales, Rupelian shales) and the distal to proximal position below the Tertiary overburden wedge (Greber et al. 2004).
- *Poor reservoir quality*: The deep wells drilled over the last hundred years in Switzerland document the rather low porosity and permeability characteristics of the potential reservoir rocks (Paleozoic clastics, Triassic clastics and dolomites, Jurassic and lower Cretaceous limestones and Tertiary clastics, for a summary see Chevalier et al. 2010). The main reasons for this rather discouraging situation are the overcompaction of the sediments related to the late uplift and erosion and a complex situation of late diagenetic overprinting and pore cementation (de Haller et al. 2011).

To a lesser extent Brink et al. (1992) men-

tioned as exploration risk factors the relatively small potential trap size for conventional accumulations in Switzerland and the absence of distinct and thick sealing sections.

Besides these geological risks it has to be considered that the seismic data is often outdated (vintages from 1970–1990) and in some areas of low density. Especially the Jura fold belt and the southern part of the Molasse Basin east of Fribourg have to be classified as «underexplored». Furthermore, several wells did never reach potential reservoir horizons below the Keuper section.

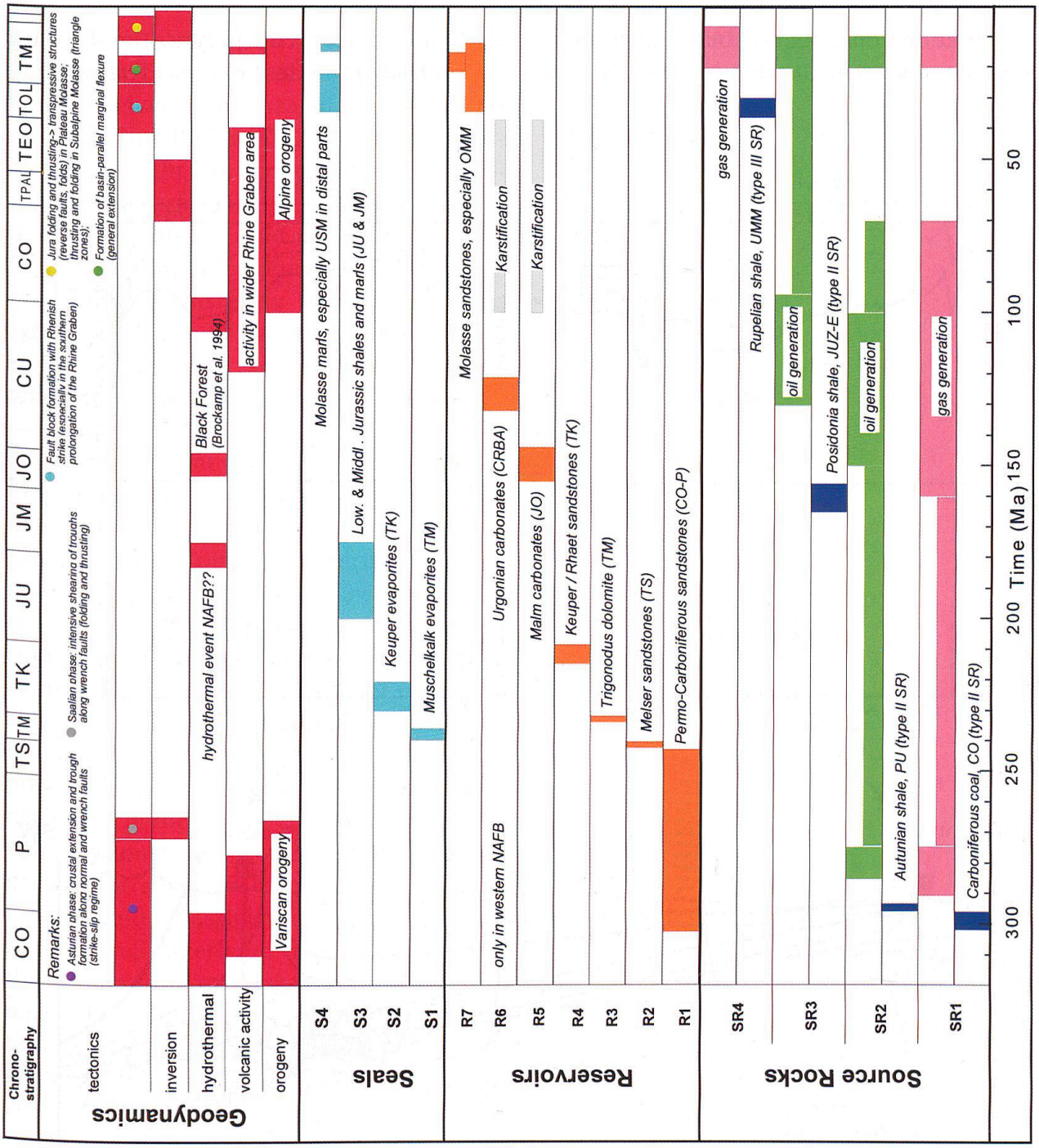

Fig. 5: Generalized petroleum systems chart for the Swiss Molasse Basin with key source rocks, generation/expulsion history, reservoir units, seals and tectonic history. This classic diagram does only present the conventional petroleum systems and not unconventional resource plays (modified from Greber et al. 2004).

5. Current exploration and outlook

Since 2005 exploration activity picked up again and today over two thirds of the Swiss Molasse Basin and the Jura Mountain area are protected by eighteen exploration permits held by seven Swiss or Swiss/foreign joint venture exploration companies (Fig. 7). These new efforts by the petroleum industry are characterized by the use of modern exploration concepts combined with reprocessing and reevaluation of the existing exploration data or even the acquisition of new seismic data (e. g. Peos-SEAG in the Gros-de-Vaud area in 2011). This new exploration phase in Switzerland concentrates mainly on four types of plays:

1. Shallow conventional oil/gas plays in the Mesozoic-Paleozoic section of the Jura Fold belt and the northern rim of the Molasse Basin (Celtique Energy, SEAG/PEOS).
2. Shallow heavy oil play in the Tertiary section of the Geneva area (Tethys Oil).

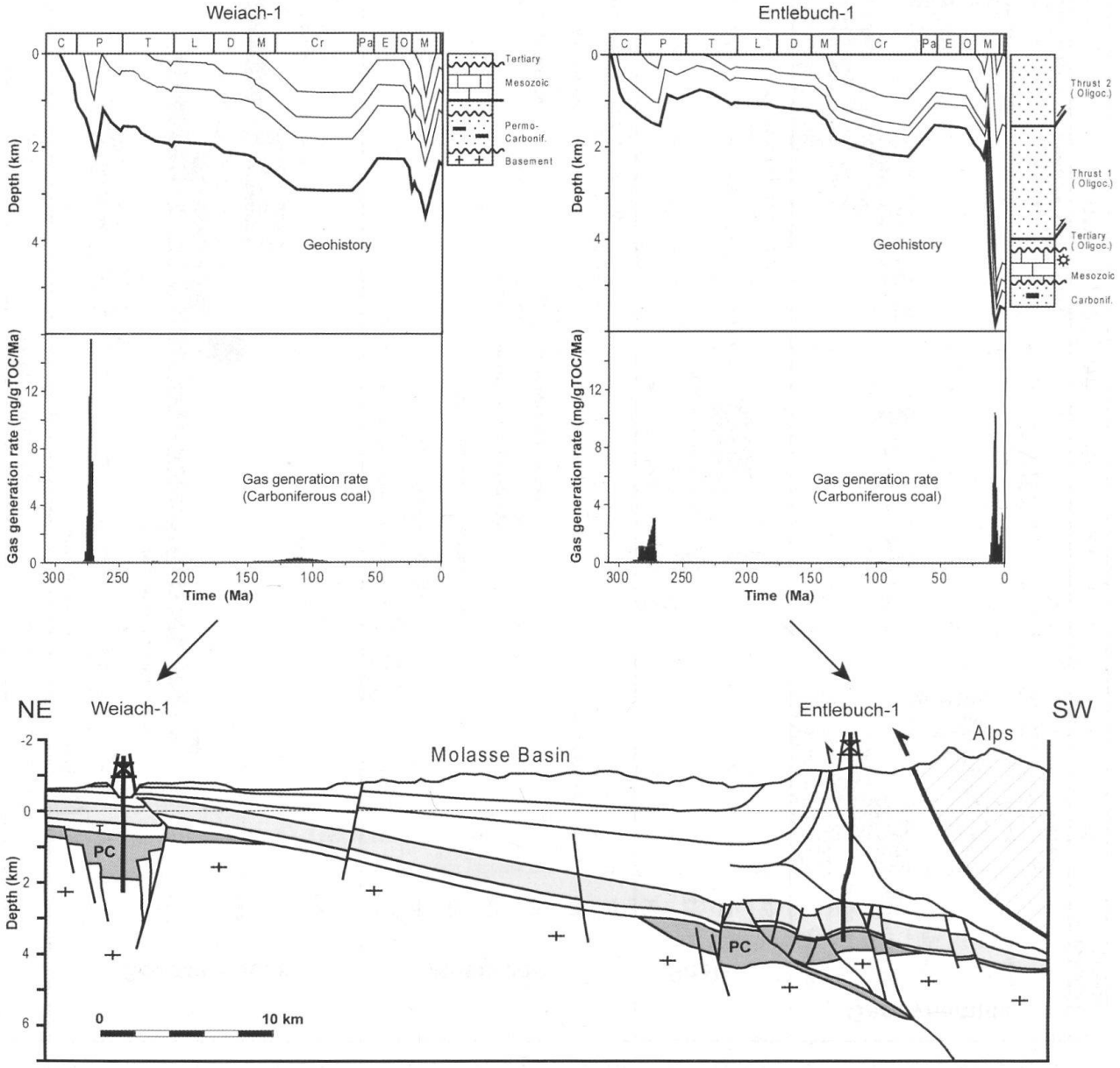

Fig. 6: Schematic cross section through the Molasse Basin from the subalpine front to northern Switzerland with two geohistory and gas generation reconstructions for well Entlebuch-1 and Weiach-1. Note the late gas charge from e. g. Carboniferous coals in the southern part of the basin. (PC: Permo-Carboniferous).

3. Deep conventional and unconventional tight gas plays in the southern part of the Molasse Basin (Petrosvibri, SEAG, GVM).
4. Unconventional shale gas play in the Jurassic section of the western Molasse Basin (e. g. Schuepbach Energy, currently inactive because of exploration ban in Canton Fribourg and hydraulic fracturing moratorium in Canton Vaud).

The newest well in Switzerland, drilled by Petrosvibri SA in the eastern Lake Geneva area, produced encouraging results: The deviated Noville-1 well (3'500 m TVD) discovered a tight gas accumulation in Paleozoic clastic rocks. Further testing in the second half of 2012 should clarify if gas from this accumulation can be produced at economic rates. Currently two other exploration wells are in the planning stage by PEOS (Hermrigen-2, south of Lake Bienne) and Celtique Energy (Noiraigue-1, Jura NE).

A new component in the Swiss exploration for hydrocarbons will clearly be the assessment of the shale gas potential (unconventional resource play). Domestic shale gas could well play a key role for Switzerland in the future energy supply mix and planned transition to a non-nuclear and low carbon environment. Despite the fact that currently shale gas exploration is banned in Cantons FR and VD and the use of shale gas and its potential environmental impact are widely discussed in the public, the recoverable gas volumes could well be substantial. So far no drilling for shale gas exploration or other related field investigations have been carried out in Switzerland. However, based on the results from existing wells and seismic data and by applying known rock parameters typically necessary for a successful shale gas play (e. g. Gillman & Robinson 2011), a first rough estimation of potential recoverable shale gas from the Aalenian-Toarcian interval results in ~50–100 Mrd. m^3. In view of the current annual Swiss gas consumption (3.5 Mrd. m^3) such volumes are worth a closer look. Only detailed investigations will demonstrate if these unconventional resources can be produced economically and without negative impact on the environment.

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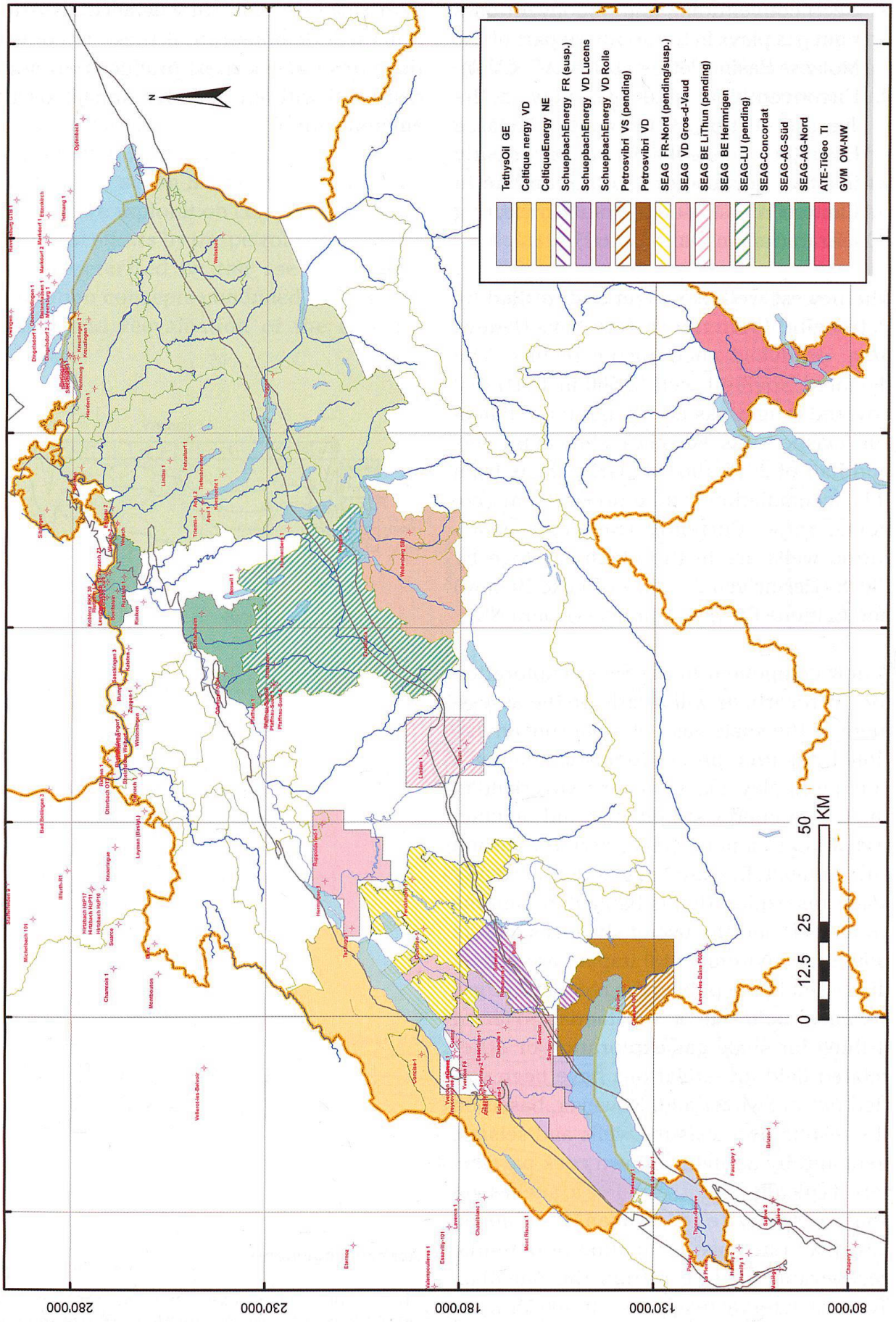

Fig. 7: Exploration permit map of Switzerland (2012) with deep wells.

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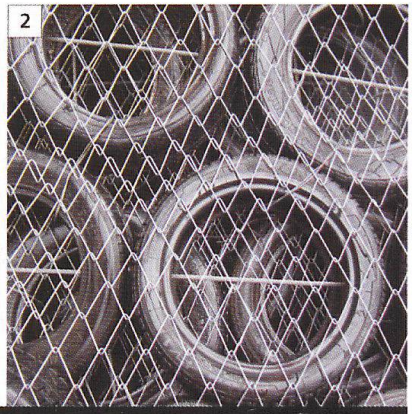

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