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Shallow hydrocarbons in Lower Austria: A drilling hazard and a valuable exploration tool

Jan MAYER & Reinhard F. SACHSENHOFER*)

KEYWORDS

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Department Applied Geosciences and Geophysics, Montanuniversität, Peter-Tunner-Str. 5, A-8700 Leoben, Austria;
*) Corresponding author, reinhard.sachsenhofer@unileoben.ac.at

Abstract

The presence of shallow gas constitutes a drilling hazard (several gas blow outs occurred recently in shallow wells in Lower Austria), but provides also a valuable tool for hydrocarbon exploration. 65 gas shows, 12 oil and gas shows, and 18 oil shows are known in Lower Austria at the surface or at shallow depth (< 300 m below surface; b.s.). Most gas shows are located in the Vienna Basin (39) followed by the Molasse Basin (28) and the Flysch Zone (13). Most oil (and gas) shows occurred in the Vienna Basin (11), the Northern Calcareous Alps (8) and the Flysch Zone (7). In addition five gas fields are present in Lower Austria, where at least one reservoir horizon is at a depth of less than 300 m b.s.

Shallow hydrocarbon shows in the Vienna Basin are connected to the foot- and hangingwall of the Steinberg, Pirawarth and Leopoldsdorf faults and hydrocarbon fields in the central part (Matzen, Fischamend) of the basin. There are only a few oil and gas shows without obvious connection to known deposits. Some hydrocarbon shows contain hydrogen sulfide, which is probably linked to the presence of Permo-Triassic gypsum/anhydrite in underlying units. The gas shows in the Molasse Basin east of the Bohemian Massif coincide with a hydrocarbon field and coal-bearing Permo-Carboniferous graben sediments. Numerous oil and gas shows are located along a north-south trend in the southern Waschberg Zone and the northeasternmost Alps (Flysch Zone, Northern Calcareous Alps). The regional distribution suggests an origin from Gresten Formation of Doggerian age. A hydrogen-rich gas show near the southern margin of the Northern Calcareous Alps is linked to evaporitic Permo-Triassic rocks near the base of the Northern Calcareous Alps. Most of the gas shows in the Molasse Basin west of the Bohemian spur are located in an area close to the river Enns. With the current data it is impossible to decide whether the gas is of biogenic origin or formed by degradation of pre-existing oil generated from Oligocene source rocks (Schöneck Formation). Whereas oil (and gas) shows occur in the Klippen Belt and the Inneralpine Molasse, pure gas shows, partly with high pressure, have been recorded in the Flysch Zone. Oil shows in the Gresten Klippen Belt are probably related to coals of the Jurassic Gresten Formation. An oil seep initiated drilling of the well Urmannsau 1 in the Northern Calcareous Alps, which encountered non-commercial oil and gas. Biomarker data suggests a source rock with relatively low maturity deposited in an anoxic environment and a significant contribution of terrestrial plants.

The knowledge of the areal distribution of shallow gas accumulations is essential to define zones with a very high risk to encounter gas at shallow depths.

Das Vorkommen von oberflächennahem Gas stellt ein Bohrrisiko dar (mehrere Gasausbrüche traten in den letzten Jahren in Seichtbohrungen in Niederösterreich auf). Gleichzeitig sind seichte Kohlenwasserstoffe aber auch ein wertvolles Hilfsmittel für die Exploration. 65 Gas-, 12 Öl- und Gas- und 18 Ölanzeichen sind in Niederösterreich an der Oberfläche und bis in eine Tiefe von 300 m unter Geländeoberkannte (u. GOK) bekannt. Die meisten Gasanzeichen traten im Wiener Becken (39), gefolgt vom Molasse Becken (28) und der Flysch Zone (13) auf. Die meisten Ölanzeichen (plus Öl- und Gasanzeichen) befinden sich im Wiener Becken (11), in den Nördlichen Kalkalpen (8) und der Flysch Zone (7). Zusätzlich treten 5 Gaslagerstätten auf, bei denen zumindest ein Gashorizont in einer Tiefe von weniger als 300 m u. GOK liegt.

Seichte Kohlenwasserstoffanzeichen im Wiener Becken stehen im Zusammenhang mit dem Steinberg Bruch, der Pirawarther Bruchzone und dem Leopoldsdorfer Bruch. Sie treten sowohl in der Liegend- als auch in der Hangendscholle auf. Weitere seichte Kohlenwasserstoffanzeichen befinden sich im Bereich von Lagerstätten im Beckenzentrum (Matzen, Fischamend). Es ist nur bei einer geringen Anzahl von Öl- und Gasanzeichen keine Verbindung zu bekannten Lagerstätten erkennbar. Einige Kohlenwasserstoffanzeichen beinhalten Schwefelwasserstoff, der vermutlich in Verbindung mit dem Auftreten von permo-triassischem Gips/Anhydrit im Untergrund steht. Die Gasanzeichen im Molasse Becken östlich des Sporns der Böhmischen Masse stehen in Verbindung mit einer Kohlenwasserstofflagerstätte und kohleführenden permo-karbonen Grabensedimenten. Zahlreiche Öl- und Gasanzeichen befinden sich entlang eines Nord-Süd orientierten Bereichs in der südlichen Waschberg Zone und den nordöstlichsten Alpen (Flysch Zone, Nördliche Kalkalpen). Die regionale Verbreitung deutet eine Herkunft aus der Gresten-Formation des Doggers an. Ein wasserstoffreiches Gas in der Nähe des Südrandes der Nördlichen Kalkalpen steht in Verbindung mit evaporitischer Permo-Trias im Bereich der Basis der Nördlichen Kalkalpen. Die meisten Gasanzeichen im Molasse Becken westlich des Sporns der Böhmischen Masse befinden sich nahe der Enns. Mangels Analysedaten ist es unmöglich zu entscheiden, ob das Gas biogener Herkunft ist, oder durch

Biodegradation eines ursprünglichen Öls entstanden ist, das in oligozänen Muttergesteinen gebildet wurden. Öl- und Gasanzeichen treten in der Klippenzone und in der Inneralpinen Molasse auf. Reine Gasanzeichen, teilweise mit hohen Drücken, wurden in der Flyschzone bekannt. Ölanzeichen in der Grestener Klippenzone stehen wahrscheinlich im Zusammenhang mit der jurassischen Grestener Kohle. Ein Ölaustritt in den Nördlichen Kalkalpen gab Anlass zur Bohrung Urmannsau 1, welche nicht-ökonomische Kohlenwasserstoffe antraf. Biomarker-Daten belegen ein gering reifes Muttergestein, welches in anoxischem Milieu mit signifikantem Eintrag von terrestrischen Pflanzen abgelagert wurde.

Die Kenntnis der Verteilung der seichten Kohlenwasserstoffanzeichen ermöglicht eine Abgrenzung von Zonen mit sehr hohem Risiko für das Antreffen von seichten Gasakkumulationen.

1. Introduction

On the 25th of July 2011 a borehole, designed as a downhole heat exchanger (DHE), erupted due to a gas blow out in a depth of 98.5 m below surface (b.s.) in St. Pantaleon-Erla (N St. Valentin; Fig. 1, 5). The blow out was only brought under control by OMV on the next day (http://noev1.orf.at/stories/529020). A similar gas-blow out occurred on the 29th of July 2005 in Herzograd/St.Valentin. During this blow out two drillers were seriously injured because of the self-ignition of the gas.

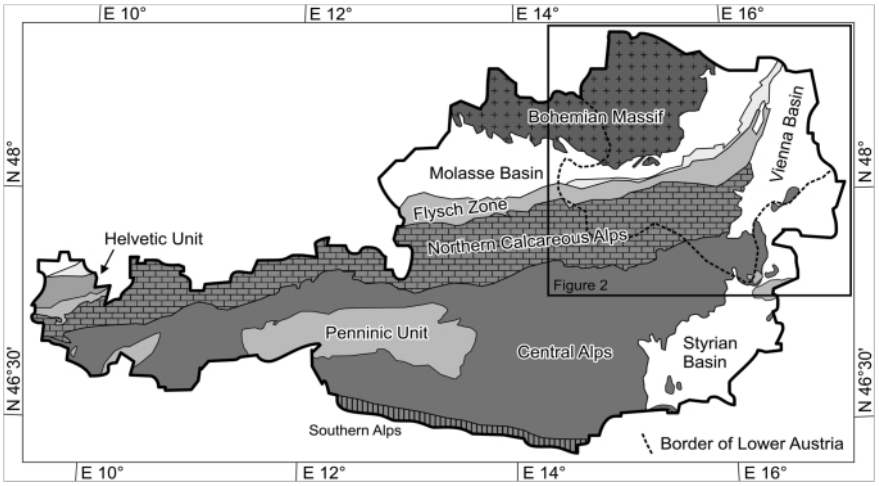

Figure 1: Geological map of Austria and area of interest.

To assess the danger of blow outs in shallow wells (<300 m depth b.s.), the federal state of Lower Austria commissioned the Montanuniversitaet Leoben (Chair Petroleum Geology) to create a database of hydrocarbon shows and to integrate it into its GIS system (NÖGIS). The threshold depth of 300 m was chosen because deeper boreholes have to be commissioned by the mining authority.

Whereas gas blow outs are an obvious danger for drillers and the population, shallow hydrocarbon shows are also a valuable tool for hydrocarbon exploration (Brix, 1993). In the present paper all known hydrocarbon seepages and shallow hydrocarbon shows are described. The aim of the paper is twofold: (1) to discuss the distribution of the hydrocarbon shows with respect to petroleum systems in Lower Austria and (2) to recognize zones with a high potential for gas blow outs in shallow wells.

Using a simple approach, the hydrocarbon shows were classified as gas shows, oil and gas shows, or oil shows (liquid or highly viscous hydrocarbons without recognizable hydrocarbon gases).

2. Geological setting

Several of the main tectonic elements of Austria are present in Lower Austria (Figs. 1, 2; Wessely, 2006):

- The Bohemian Massif comprises metamorphic and magmatic rocks of the Varsican basement.
- The Molasse Basin comprises the Northern Alpine Foreland Basin. It is filled with Upper Eocene to Upper Miocene sedimentary rocks. Typically, these rocks directly overlie the crystalline basement of the Bohemian Massif. Only in the eastern part of Lower Austria, Permo-Carboniferous and autochthonous Mesozoic rocks underlie the Molasse Basin (Fig. 3).
- The thrust sheets of the Waschberg Zone include Mesozoic rocks deposited on the Bohemian Massif, and Paleogene to Lower Miocene Molasse sediments. The Inneralpine (Parautochthonous) Molasse comprises sediments deposited on Flysch thrusts, which have been involved in the nappe stacking.
- The Flysch Zone is composed of uppermost Lower Cretaceous to Eocene deep water sediments. Several “Klippen Belts” can be traced along the margin and within the Flysch Zone. The (Ultra-)Helvetic Gresten Klippen Belt includes coal measures (Liassic Gresten Fromation).
- The Northern Calcareous Alps comprise a Permian to Paleocene successions with a thick carbonate development of Triassic and Jurassic age. Their former Paleozoic basement is represented by the Greywacke Zone.
- The Central Alps and the Tatrides are formed by crystalline complexes and a Paleozoic and Mesozoic cover.
- The Vienna Basin, filled by Miocene sediments, is superimposed on various nappe units.

Oil and gas deposits in Lower Austria occur mainly in the Miocene fill of the Vienna Basin, but also in the Northern Calcareous Alps beneath the Miocene sediments, in the Waschberg Zone, in the Molasse Basin and in the authochthonous Mesozoic (Fig. 3).

According to present understanding, most hydrocarbons in the Vienna Basin were generated in the Malmian Mikulov For-

mation (Autochthonous Mesozoic; Ladwein, 1988) and migrated along faults through the Alpine thrust complex. Gas fields in the central basin SW of Orth contain biogenic gas (Schoell, 1984; Ladwein, 1988). The Zwerndorf Field contains thermogenic gas with an admixture of biogenic gas. Gas/condensate and oil produced from autochthonous Mesozoic sediments beneath the Flysch Zone (Höflein Field) and the Waschberg Zone may have a contribution of hydrocarbons generated in the coal-bearing Gresten Formation of Doggerian age (Kratochvil and Ladwein, 1984; Ladwein, 1988; Sachsenhofer et al., 2006). Gas of mixed biogenic / thermogenic origin has been found in shallow Miocene horizons in the Roseldorf Field (Waschberg Zone). Gas in the Molasse Basin is of biogenic origin (Schoell, 1984).

3. Data acquisition

The study is based on an extensive literature survey. The most important reference was Brix (1993), who listed 40 hydrocarbon shows in Lower Austria (incl. Vienna). Brix (1993) includes numerous unpublished references, which are not listed in the present paper. The literature survey also considered natural gas fields, where at least one reservoir horizon is at a depth of less than 300 m b.s. (Brix and Schultz, 1993), and blow outs of hydrocarbon exploration wells (Spörker and Logigan, 1988), because they might have caused gas migration into shallow horizons.

In addition, the reports of 2595 counterflush (CF) boreholes, drilled during the 1930ies and 40ies for structural investigations, were inspected for hydrocarbon shows.

Finally, a total of 164 drilling companies, geological engineering bureaus, experts, and district commissions (Bezirkshauptmannschaften) were asked to provide data on gas and oil shows. Fearing negative publicity, some companies obviously withheld the needed information, or provided it only after signing confidentiality agreements.

Because of the confidentiality issues, only published information is added in the reference list. The focus of the study is Lower Austria. Hydrocarbon shows beyond its border have also been recorded. As the focus was on Lower Austria the data acquisition in those additional areas is not complete.

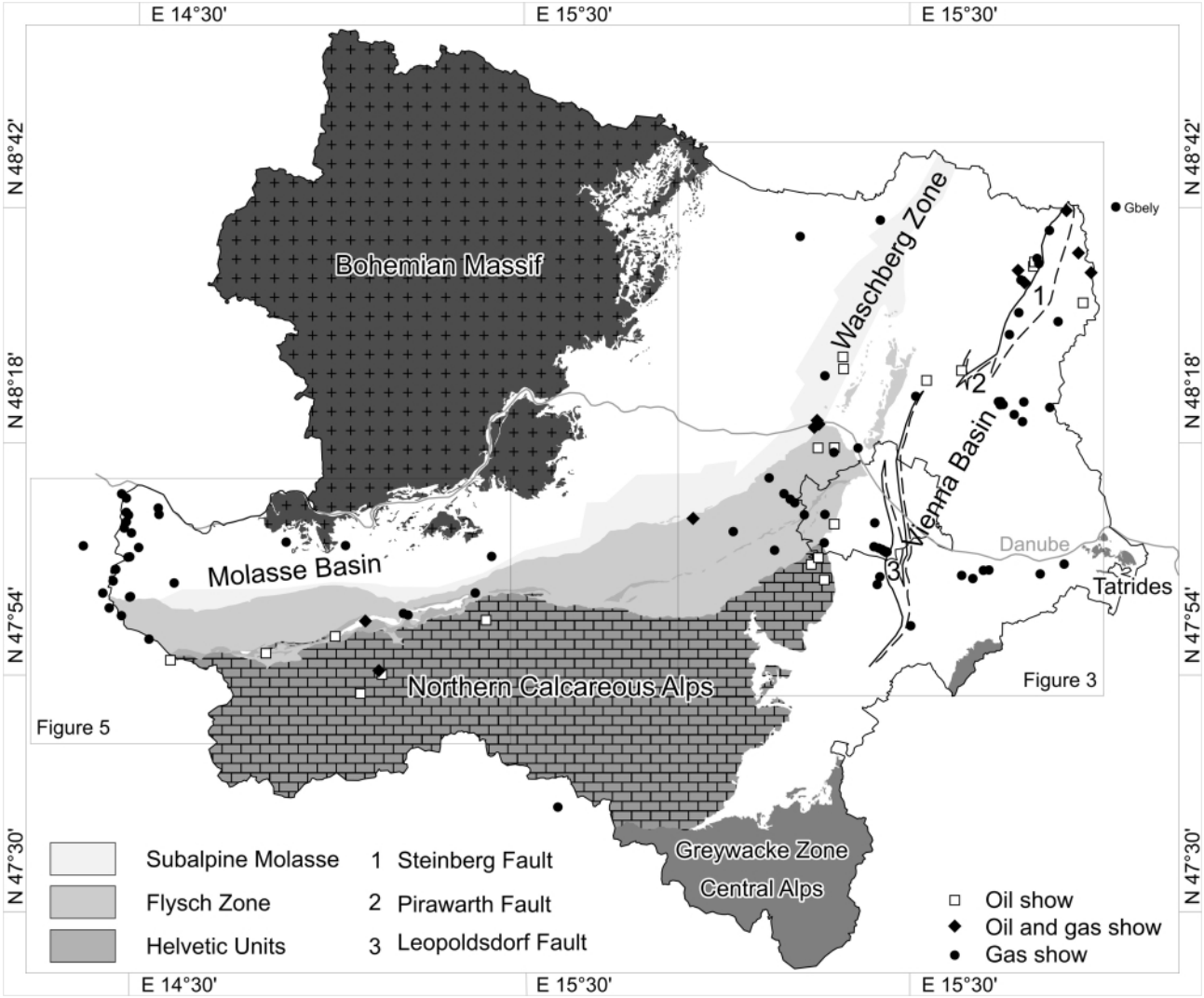

Figure 2: Geological map of Lower Austria with position of gas, oil and gas, and oil shows. Rectangles mark positions of Figs. 3 and 5. The position of the Steinberg and Leopolsdorf fault systems are shown after Wessely (2006).

4. Results

4.1 Hydrocarbon shows

65 gas shows, 12 oil and gas shows, and 18 oil shows are known to occur in Lower Austria at the surface or at a depth of less than 300 m b.s. (Table 1, Fig. 2). Another 15 gas shows (10 in Vienna, 5 in Upper Austria, 1 in Styria), a single oil show (asphalt) in Upper Austria and one oil show in Vienna occurred close to the border of Lower Austria.

Type of Show	Vienna Basin	Molasse Basin	Waschberg Zone	Flysch Zone	Klippen Belt	Northern Calacareous Alps
Gas	29 (10)	23 (5)		12 (1)		(1)
Oil and Gas	5	2		4		1
Oil	5 (1)		2	3	2	6 (1)
Shallow Gas Field	3		2			

Table 1: Numbers of hydrocarbon shows in different geological units of Lower Austria. Numbers of shows outside of Lower Austria are shown in brackets.

Most gas shows are located in the Vienna Basin (39) followed by the Molasse Basin (28) and the Flysch Zone (13). Most oil (plus oil and gas) shows occurred in the Vienna Basin (11), the Northern Calcareous Alps (8) and the Flysch Zone (7).

4.2 Shallow gas fields

Shallow (< 300 m b.s.) gas fields have been produced in the Vienna Basin (Althöflein, Gösting, Oberlaa) and the Waschberg Zone (Merkersdorf, Roseldorf) (Fig. 3).

4.3 Blow outs at hydrocarbon exploration wells

Thirteen blow outs occurred between 1935 and 1952 at hydrocarbon exploration wells (Spörker and Logigan, 1988) in Lower Austria (Fig. 3). Gas migration into shallow horizons caused by a blow out is proven for the Mühlberg 1 well, where a major blow out in the year 1941 caused a successor blow out in an abandoned shallow CF well located about 250 m east of Mühlberg 1.

5. Discussion

5.1 Geological setting of hydrocarbon shows

5.1.1 Gas and oil shows in the Vienna Basin

The discovery of the gas seepage in Gbely (Egbell) in Slovakia, detected in 1912 by Jan Medlen, led to the detection of the first oil reservoir in the Vienna Basin (Wessely, 2006).

There is an obvious connection between hydrocarbon shows, gas and oil fields and major fault zones (Fig. 3). Most hydrocarbon shows are aligned along the fault systems (Steinberg, Pirawarth, Leopoldsdorf faults) bounding the depocenters of the Vienna Basin towards the west.

- A high number of oil and gas shows and also gas fields with shallow reservoir horizons (Althöflein: Badenian; 225-

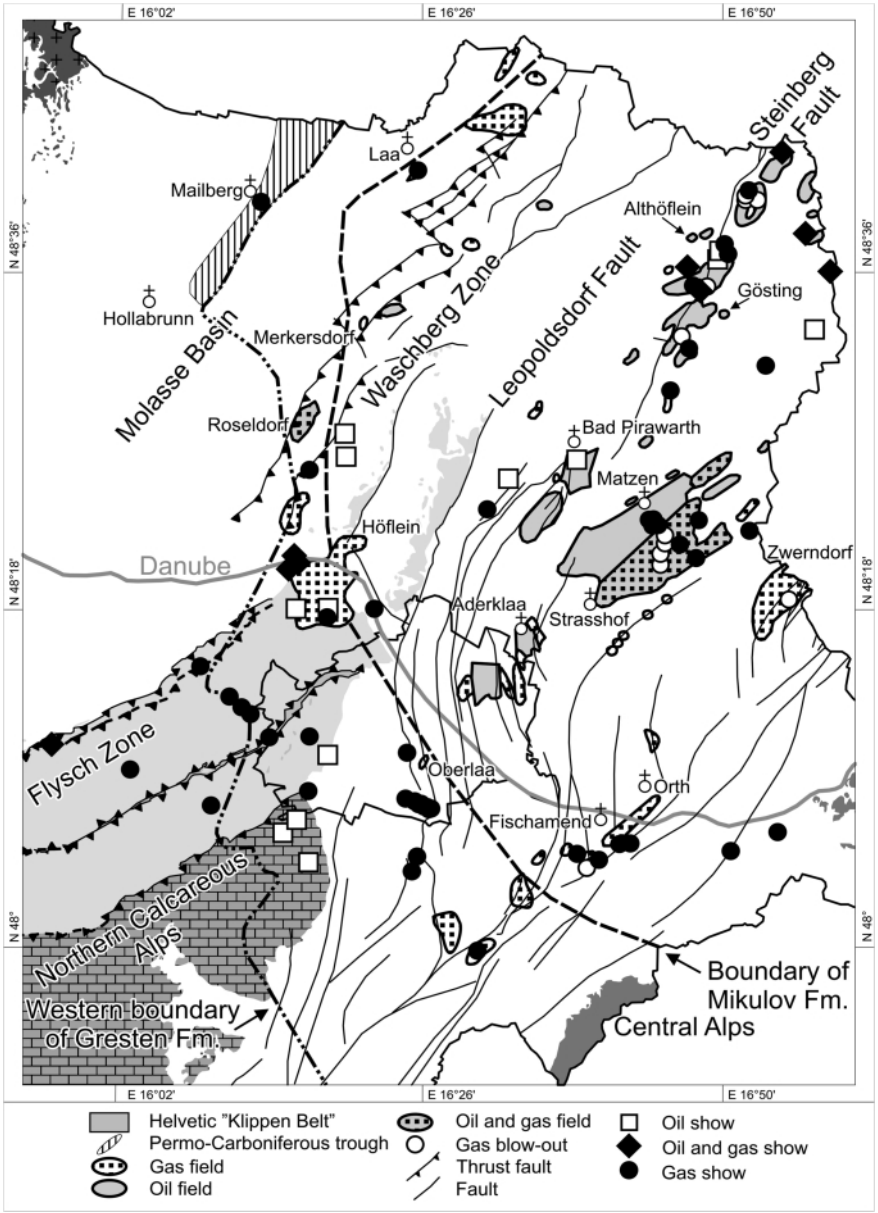

Figure 3: Position of hydrocarbon fields (Arzmüller et al., 2004), hydrocarbon shows and blow outs in the eastern part of Lower Austria. The distribution of potential source rocks (Permo-Carboniferous; Gresten Fm., Mikulov Fm.) is shown (Kröll and Wessely, 2001).

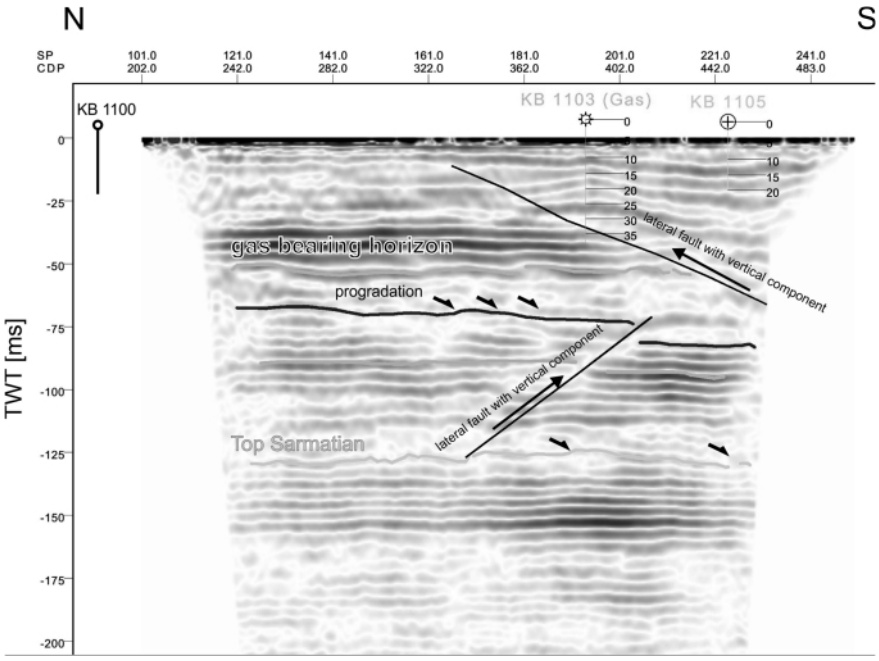

Figure 4: N-S trending 150 m long seismic section (time domain in ms) along a 35-m-deep and 20-cm-thick gas bearing horizon in the Oberlaa High. Despite its low thickness, it causes an amplitude anomaly (bright spot). This shows that the extension of shallow gas can be detected using high resolution reflection seismic even in urban areas (Schreilechner and Eichkitz, 2013).

232 m b.s.; Gösting: Upper Pannonian) occur in the footwall and in the hangingwall of the Steinberg Fault (Friedl, 1937; Streintz, 1933; Brix, 1993).

- Hydrocarbon shows occur in the footwall (Kronberg – Pirawarth High) and in the hangingwall (above Pirawarth Field) of the Pirawarth Fault.
- Several gas shows, including a blow out in a shallow exploratory well for the subway in Vienna in 2009 (Schreilechner and Eichkitz, 2013; Fig. 4), and the small Oberlaa Field (Badenian, 262-266 m b.s.) have been recorded in the footwall of the Leopoldsdorf Fault System (Oberlaa High). The gas fields St. Marx (Badenian; 410-427 m b.s.) and Favoriten (Sarmatian; 714-730 m b.s.) produced gas from the Leopoldsdorf Fault System, suggesting that the Oberlaa gas migrated along this major fault system, which is currently under extension and a potential migration pathway. Oil shows in the St. Marx 1 well suggest that the gas is thermogenic in origin.

Apart from the basin margin faults, gas shows with a strong smell of hydrogen sulfide have been recorded from the central high of the Vienna Basin above the giant Matzen Field. Notably, no hydrocarbon shows have been recorded so far above the Aderklaa and Zwerndorf fields.

In contrast, gas (with H_2S) was detected above fields with biogenic gas in the central zone of the Vienna Basin south of river Danube (e.g. Enzersdorf-Fischamend, S of Orth). Here, active strike slip faulting along the basin center fault caused an updoming of Sarmatian sediments and might be responsible for hydrocarbon migration into shallow horizons.

Apart from the hydrocarbon shows mentioned above, which can be easily linked to underlying hydrocarbon fields, there are only a few oil and gas shows without obvious connection to known deposits.

Considering the origin of the hydrocarbon deposits (Ladwein, 1988), it is likely that most of the oil and gas shows represent hydrocarbons generated from the Malmian Mikulov Formation (Fig. 7). However, considering the biogenic origin of gas southwest of Orth, a similar origin is assumed for gas shows in this area (e.g. Fischamend). The vertical arrangement of a mature source rock (Mikulov Fm.), a high number of hydrocarbon reservoirs in different stratigraphic positions above the hydrocarbon kitchen, and hydrocarbon seeps are typical for overcharged, vertically drained petroleum systems (Demaison and Huizinga, 1994).

Many gas shows in areas underlain by the Northern Calcareous Alps (Matzen, Oberlaa) and the Central Alps (Fischamend) contain hydrogen sulfide. In contrast, hydrogen sulfide has not been recorded from gas shows in the northern part of the Vienna Basin underlain by the Flysch Zone. This observation suggests a genetic link to the presence of Per-

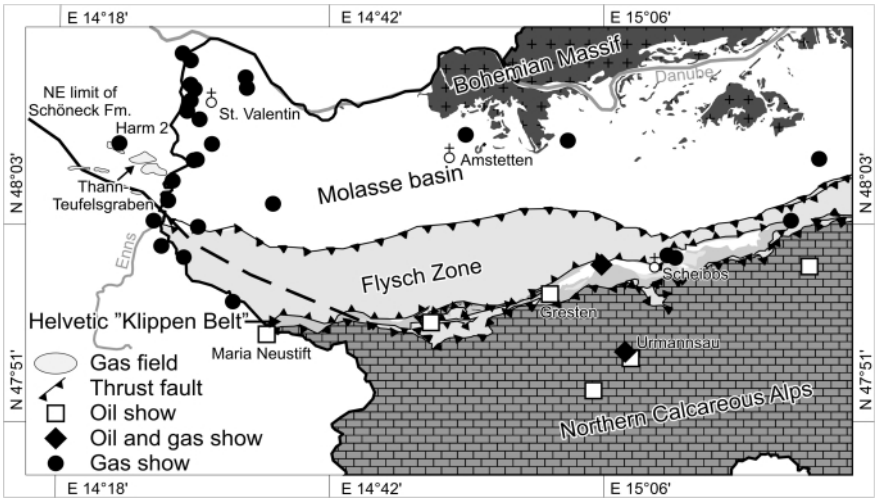

Figure 5: Geological map of the western part of Lower Austria together with the positions of gas, oil and gas, and oil shows. The position of some gas fields in Upper Austria and the eastern boundary of Oligocene source rocks (Sachsenhofer and Schulz, 2006) are also shown.

mo-Triassic gypsum/anhydrite and sour gas in basement units.

5.1.2 Gas and oil shows in the eastern part of the Molasse Basin, the Waschberg Zone, and the eastern sector of the Alps

Only two gas shows are known from the Molasse Basin east of the Bohemian Massif. One might be related to the small Laa Field, the other one (near Mailberg) coincides with Permo-Carboniferous graben sediments beneath the Molasse Zone. Although analytical data are not available, we speculate that the latter show might be related to coal-bearing Carboniferous rocks (Fig. 3). This would resemble the situation in Switzerland, where the country´s only gas field (Entlebuch) is charged by Permo-Carboniferous coal measures (Veron, 2005).

Two oil shows and one gas show occur in the southern part of the Waschberg Zone (Vetters, 1921). Hydrocarbon deposits in this area occur at depths of up to 4 km in the autochthonous Mesozoic and in shallow, deformed Cenozoic (and Cretaceous) sediments. The latter include gas accumulations at Merkersdorf (Ottnangian; 200-255m b.s.) and Roseldorf (250 to >1550 m b.s.; Brix, 1993).

Further to the south, gas and oil shows have been detected in the eastern part of the Flysch Zone (e,g. hydroelectric power station Greifenstein; Vetters 1921; Waagen, 1931; Streintz, 1933; Schwingenschlögl, 1984) and are often related to faults. The gas dryness ($C_1/[C_2+C_3]$ = 44-49) suggests a thermal origin (unpublished data from 2008). Oil shows occur in the easternmost sector of the Northern Calcareous Alps (Brix, 1993).

The regional distribution of shallow gas and oil shows in the Waschberg Zone and near the eastern margin of the Flysch Zone / Northern Calcareous Alps suggests an origin from the Doggerian Gresten Formation (Fig. 7). The hypothesis is further supported by petroleum deposits in the Gresten Formation itself and in the Autochthonous Mesozoic sediments overlying it. The origin of gas and oil shows in the Flysch Zone east of the areal extent of the Gresten Formation (Fig. 7) is less obvious.

A gas show was detected in 1968 in in the Schneealpen tunnel near the southern margin of the Northern Calcareous Alps (Fig. 2; Gattinger, 1973). The hydrogen-rich gas escaped from anhydrite within the Lower Triassic Werfen Formation and was relatively dry ($C_1/[C_2+C_3]$ = 118). Although an origin from the Werfen Formation cannot be excluded, the gas accumulation was probably charged by evaporitic Permo-Triassic rocks near the base of the Northern Calcareous Alps. Similar gas exhalations are frequently encountered in Alpine salt deposits (Schauberger, 1960).

5.1.3 Gas and oil shows in the Molasse Basin west of the Bohemian Spur

A high concentration of gas shows, partly with relatively high pressure (> 5 bar), is found in the Molasse Basin close to the river Enns and east of St. Valentin (Holzleitner, 1926; Fig. 5).

For the discussion of their origin, the following observations made close to the border in Upper Austria are important:

- The boreholes Steyr 1 (245-247 m b.s.) and Harmannsdorf 2 (145 m b.s.) drilled subeconomic shallow dry (biogenic?) gas ($C_1/[C_2+C_3]$ = 425-575) in Lower Miocene horizons.
- Slightly deeper gas deposits (550-730 m) in Eocene and Upper Cretaceous horizons (e.g. Thann-Teufelsgraben, Harmannsdorf) are underlain by a heavy, biodegraded oil (Gratzer et al., 2011). Based on (rare) isotope and compositional data, Reischenbacher and Sachsenhofer (2011) argue that these gas deposits formed by biodegradation of pre-existing oil deposits.
- Uplift of the easternmost part of the Upper Austrian Molasse Basin resulted in westward tilting of Molasse sediments and controlled migration paths (Gusterhuber et al., 2012).

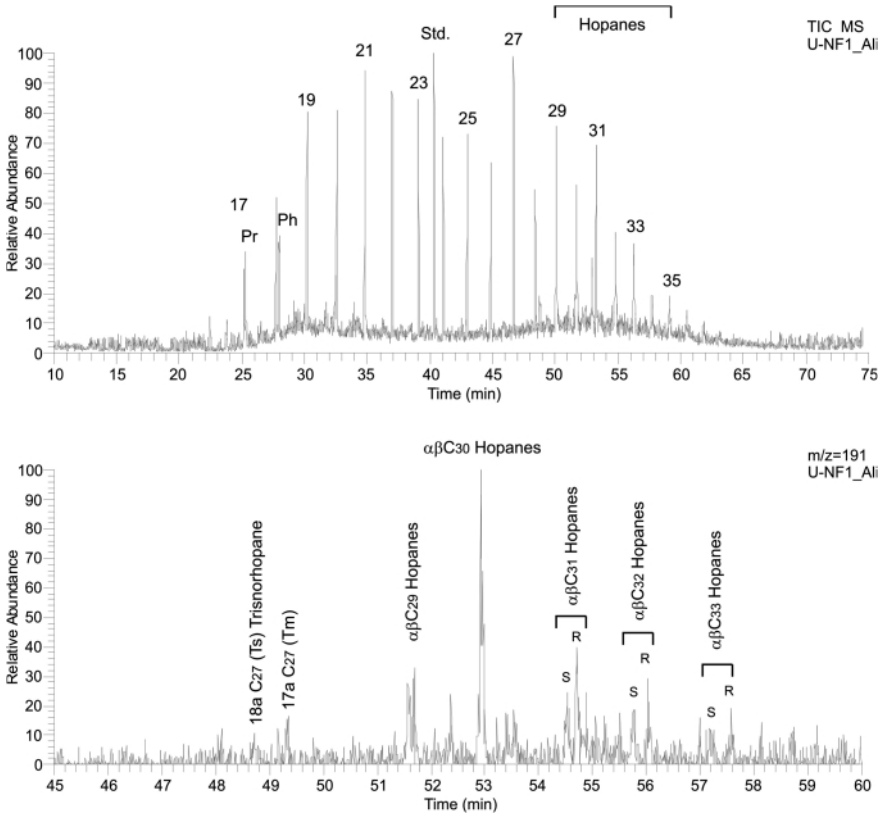

Figure 6: Chromatogram (Total Ion Current) of the saturated hydrocarbon fractions and mass chromatogram (m/z 191) for triterpanes of the Urmannsau rock extract. n-Alkanes are labeled according to their carbon number. Pr. = pristane, Ph = phytane, Std. = deuterated tetracosane. Tm = 17a(H) trisnorhopane.

Without molecular and isotopic data of the gas shows, it is impossible to decide whether the gas detected in Lower Austria is of biogenic origin or formed by degradation of a pre-existing oil deposit charged by Oligocene source rocks (Schöneck Formation). The eastern limit of this source rock is indicated in Figure 5 and possible migration directions are shown in Figure 7. Thus, geochemical data is needed urgently to understand the petroleum potential of the Molasse Basin in Lower Austria.

A gas show close to Amstetten was encountered while drilling for coal in the middle of the 19th century (Vetters, 1921, 1937).

5.1.4 Gas and oil shows in the Inneralpine Molasse, the Klippen Belt and the Flysch Zone of western Lower Austria

Oil shows in the "Inneralpine Molasse" west of Scheibbs resulted in the drilling of the 461 m deep Rogatsboden 1(1a) exploration well (Prey, 1957). The well encountered gas and oil shows in the Inneralpine Molasse, the Klippen Belt and the Flysch Zone. In a similar tectonic situation a gas explosion occurred 18 km east of Scheibbs in Glosbach (Götzinger, 1931 a,b). The explosion occurred within Flysch sediments, which are in close contact to Inneralpine Molasse sediments and the Klippen Belt.

Whereas oil (and gas) shows occur in the Klippen Belt and the Inneralpine Molasse, pure gas shows, partly with high pressure, have been identified in the Flysch Zone. A gas accumulation encountered in a tunnel NE Scheibbs (Hochpyhra tunnel) was burning for 14 days (Jenikowsky, 1934; Vetters, 1937, 1938; Brix and Schultz, 1993). The source rock of the gas remains unknown.

Oil shows (including asphalt) occur in rocks of the Gresten Klippen Belt between Maria Neustift in the west and Gresten in the east (Fig. 5; Petrascheck, 1924; Sigmund, 1937; Vetters, 1938; Brix, 1993). Probably they are related to the Jurassic Gresten coal, which is often bituminous and reaches oil window maturity (Sachsenhofer, 1987).

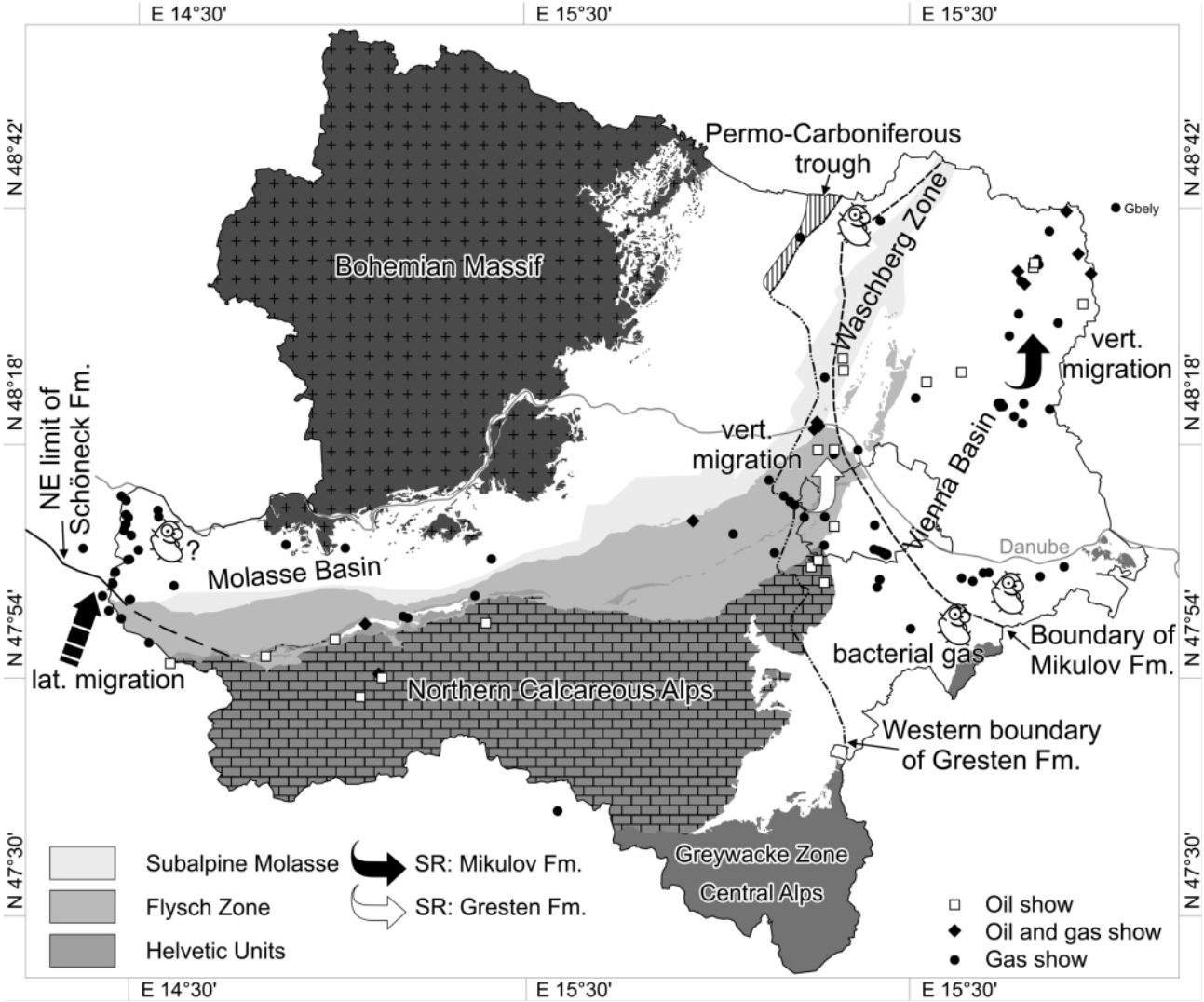

Figure 7: Geological map of Lower Austria together with the positions of gas, oil and gas, and oil shows. The supposed origin, migration pathways and position of the shallow gas and oil shows are shown. The eastern boundary of Oligocene source rocks (Sachsenhofer and Schulz, 2006) and the distribution of potential source rocks (Permo-Carboniferous; Gresten Fm., Mikulov Fm.; Kröll and Wessely, 2001) are also shown.

5.1.5 Gas and oil shows in the Northern Calcareous Alps of western Lower Austria

There are several oil (and gas) shows in the Northern Calcareous Alps in the western part of Lower Austria (Brix, 1993; Fig. 5). The oil from the most prominent one, near Urmannsau, was used by monks from the nearby charterhouse Gaming as fuel for lamps and for pharmaceutical purposes (Ruttner, 1963; Wessely, 2006). The oil seep led to the drilling of the hydrocarbon exploration well Urmannsau 1 (Schaffer 1941; Kröll and Wessely, 1967). Although the well encountered oil and gas (e.g. at 274 m depth), no commercial hydrocarbons were found. The oil showed a sulfur content of 0,69% (Suida and Pöll, 1933). The Urmannsau oil seep is no longer visible, but Quaternary conglomerates with a strong petroleum smell occur near the river Erlauf. These gravels have been extracted and analyzed by R. Gratzer (Fig. 6). A significant odd-even predominance and a pristane/phytane ratio of 0.7 suggest a source rocks with relatively low maturity deposited in an anoxic environment and a significant contribution of terrestrial plants. Notably the extract is not (heavily) biodegraded. Obviously additional investigations are needed to decide whether the Urmannsau oil was generated from Oligocene Molasse sediments beneath the Alps, or from source rocks within the Northern Calcareous Alps.

5.2 Areas with geological hazard of hydrocarbons in shallow wells

Although the information on shallow gas is certainly biased by the population density and the number of observation points (e.g. number of water wells and shallow boreholes), zones with variably high risk for drilling shallow gas charged sediments can be recognized. It will be the responsibility of the authorities to specify drilling techniques, safety equipment and special training for drillers in areas with a high risk. Furthermore, it should be obligatory for drilling companies to communicate gas shows to the authorities.

- Vienna Basin: There is a high risk to drill natural shallow hydrocarbons above oil and gas fields. In addition, blow outs during the early days of hydrocarbon exploration (before 1955) may have caused gas migration into shallow horizons (e.g. Mühlberg, Matzen). A high risk also exists in the footwall of the major fault systems (Steinberg, Pirawarth-Hochleiten, Leopoldsdorf faults) bordering the depocenters to the west (e.g. Kronberg – Pirawarth High SW Pirawarth, Oberlaa High). Continuing extension in these areas facilitates migration of hydrocarbon gas into shallow horizons or even to the surface. Apart from these “hot spots”, shallow gas may be encountered in the entire Vienna Basin, which is characteristic for an active petroleum system.
- Molasse Basin: Shallow gas occurs in different parts of the Molasse Basin. However, the area close to the Upper Austria border is especially hazardous.
- Flysch Zone / Klippen Belt: Hydrocarbon shows are known along the entire Flysch Zone / Klippen Belt in Lower Austria. The high density of gas and oil shows in its easternmost segment proves an especially high risk. Fault zones are potentially dangerous.
- The Northern Calcareous Alps are an area with a low population density. It is possible that this results in an underestimation of the gas hazard. In any case, the possibility of the appearance of shallow hydrocarbons always has to be taken into account. The risk is especially high in areas with evaporitic Permo-Triassic successions.
- No shallow gas has been recorded so far from the Bohemian Massif, the Greywacke Zone and the Central Alps.

The above compilation shows that several zones with a very high shallow gas hazard exist in Lower Austria. To further assess the shallow drilling hazard, we suggest to test different techniques (e.g. surface geochemistry, high resolution seismics) to delineate the extension of the shallow gas accumulations in different geological settings (e.g. Oberlaa High, Molasse Basin near St. Valentin).

6. Conclusions

Shallow (< 300 m b.s.) hydrocarbon shows are known in Lower Austria in the Molasse Basin, the Flysch Zone, the Waschberg Zone, the Vienna Basin and the Northern Calcareous Alps. The position of the shallow oil and gas shows, their supposed origin and migration pathways are shown in Figure 7.

A shallow gas risk exists in all geological units with known shallow hydrocarbon shows. The risk is especially high in the Vienna Basin above known hydrocarbon deposits and along major faults, in the northeasternmost part of the Flysch Zone, and in the Molasse Basin and Flysch Zone in the western part of Lower Austria.

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Jan MAYER & Reinhard F. SACHSENHOFER*)

Department Applied Geosciences and Geophysics, Montanuniversität, Peter-Tunner-Str. 5, A-8700 Leoben, Austria;

*) Corresponding author, reinhard.sachsenhofer@unileoben.ac.at