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Did Nagra's Weiach Borehole Bypass a Gas Field?

The Pecos Slope Gasfield in New Mexico: A Model for similar Gas Occurrences in Northern Switzerland, possibly overlooked at Weiach

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Abstract

Using the producing Pecos Slope gas field in New Mexico as an analogue model, Nagra's Weiach well of 1983 in northern Switzerland may unnoticingly have drilled through a substantial commercially exploitable accumulation of natural gas in tight Permian sandstones. This seemingly absurd hypothesis is supported by the great similarities of the Permian redbeds at both locations, and by the evidence of significant gas shows in intervals of potential reservoir rocks in association with mature source rocks at Weiach. The analogue between Weiach and Pecos Slope includes also a typical log response, and the presence of fractures.
The Pecos Slope gas field remained undiscovered for 26 years, despite many wells drilled through the pay section before. Production at Pecos Slope is not controlled by a closed structure.

Zusammenfassung

Gemäss dem Analogmodell der Erdgasförderung aus dem Pecos Slope Gasfeld von New Mexiko, USA, ist es möglich, dass die Sondierbohrung Weiach der Nagra von 1983 in dichten Sandsteinen des Permokarbon-Intervalls unbemerkt eine bedeutende, wirtschaftlich ausbeutbare Lagerstätte von Erdgas durchfahren hat. Diese scheinbar absurde Hypothese stützt sich auf die Nachbarschaft des Permokarbons von Weiach zu thermisch reifen Muttergesteinen, auf die ungewöhnlich grosse Ähnlichkeit der Rotliegend-Schichten an beiden Orten, auf deutliche Gasanzeichen in Weiach und auf die ähnlichen typischen Indikationen auf den Bohrlochdiagrammen, sowie auf die Anwesenheit von Klüften.
Die Lagerstätte Pecos Slope wurde 26 Jahre lang übersehen, obschon vor der Entdeckung mehrere Bohrungen die produktive Zone unbemerkt durchfahren hatten. Die produktive Erdgas-Lagerstätte von Pecos Slope besteht unabhängig von einer geschlossenen Struktur.

1. Overview

From reading a paper by Broadhead (1984), the present reviewer was struck by intrigueing geological similarities of a producing gas reservoir in the southern United States, in comparison to Rotliegend redbeds cored in 1983 at Weiach in Northern Switzerland. At Weiach, despite clear indications of hydrocarbon gas, no procedures were performed for testing this indication. But after all, Nagra's Weiach borehole was not designed for testing gas. It was drilled for exploring nuclear waste disposal sites in basement rocks, with gas regarded as a nuisance rather than an as-

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set. But apart from that omission, Nagra's Weiach borehole must be one of the best documented wells in Europe (Matter et al. 1988).

In 1993, the author had an opportunity to meet the author of that paper, Ronald F. Broadhead, at the Geological Survey of New Mexico in Socorro N.M. The visit gave an opportunity to study and sample Abo redbeds, outcropping in the vicinity of Socorro, guided by Broadhead. Abo redbed sandstones and siltstones are the productive reservoirs in the Pecos Slope gas field north of the city of Roswell in New Mexico. These tight rocks have properties that appear unlikely at first sight, for qualifying as a gas producing reservoir. On top of that, the kind of trapping conditions at the Pecos Slope Field appears even more unusual.

Publications by Broadhead (1984), Bentz (1992), and Dutton et al. (1993) contain detailed descriptions and technical data on the Pecos Slope Field.

The help of Ben E. Law to contact Broadhead and to collect information on Pecos Slope and on the characteristics of tight gas reservoirs in general, is herewith gratefully acknowledged. At the time, Ben Law was a member of the Energy Resource Survey Team of the U.S. Geological Survey in Denver, Colorado.

At Pecos Slope, until the end of 1990, 272.7 Bcf (some 7.7 x 10^9 m^3) of gas were produced from Lower Permian redbeds. That volume equals three times the present gas consumption of Switzerland. Producible reserves of the Pecos Slope gasfield are estimated at 750 Bcf (about 21 x 10^9 m^3).

The gas at Pecos Slope occurs in a situation with the following pecularities:

- No structural trapping recognizable: The gas field is located on a gradually southeast dipping flank of the Delaware/Permian Basin, with no recognizable structural closure.
- The reservoir in the Pecos Slope gas field consists of tight red arkosic sandstones of a type also prominent in the Permian at Weiach. At both locations the fine to silty sandstones originate from fluvial channel deposits.
- Porosities of the productive sandstones at Pecos Slope range from 12-14%, mainly consisting of microporosity, not readily visible from naked eye. The pores of the rock are partly reduced by deposits of clay minerals and hematite. The Rotliegend of Weiach contains exactly the same type of rocks.
- Average permeabilities of the sandstones are similarly very low at both locations, ranging from 0.03 to 0.05 millidarcies (3 - 5 x 10^{-10} m/s). This is a range commonly regarded as non-prospective by many operators.
- Cleavages and fractures of tectonic origin are decisive for the gas production at Pecos Slope. Similar tectonic forces seem to have affected the Permocarboniferous rocks at Weiach.
- The fractures and cleavages at Pecos Slope are probably related to strike-slip faulting, locally expressed as so-called *flower structures*. From seismic evidence, deformations of a similar type appear to occur in the Permocarboniferous interval in the Weiach area, too.
- At Pecos Slope, the upper boundary of the reservoir gradually dips from 2550 ft (777 m) in the west to 4700 ft (1432 m) in the east. Weiach is situated on a structural flank at somewhat greater depth. In view of incomplete seismic coverage, it is not proven yet whether structural trapping is involved at Weiach.
- The thickness of the Pecos Slope reservoirs totals 250-450 ft (76-137 m) gross, with an average net thickness of 30 ft (9.1 m) to a maximum of 80 ft (24.4 m). At Weiach, corresponding thicknesses are many times as large.
- The age of the Upper Abo redbeds of Pecos Slope has been indirectly identified

as Lower Permian (Autunian to Saxonian), strikingly similar to the age of the Paleozoic Upper Trough Fill at Weiach.

- The top seal at Pecos Slope consists of anhydritic intercalations. The nature of the lateral seals has not been satisfactorily explained yet. It may be caused by capillarity effects, or consist of the dynamic boundary of a one-time larger, and now gradually shrinking gas accumulation.
- At Weiach, evaporitic beds near the base of the overlying Mesozoic appear to extent laterally over a large area. They could also form a good top seal for any gas accumulations. For lateral seals at Weiach, several possibilities are imaginable, including strucural closure, faulting, porosity and permeability barriers, and capillarity effects. None of them are proven at this stage.
- Reservoir pressures are below normal in the Pecos Slope field. Abnormal pressures (overpressures or underpressures) are typical for tight reservoir pays. Pressures at Weiach are above normal in the prospective interval.

2. Important Observations

- The gas accumulation at Pecos Slope was bypassed for 26 years! This happened despite quite a number of exploration holes that were drilled within the limits of the gas field. Those wells were drilled for oil and gas objectives at deeper levels. The gas potential of the Abo sandstones was not made evident by any of them. This intriguing fact recalls a similar experience with 85 unsuccessful wells drilled into the Deep Basin in Western Canada, prior to the discovery of the huge Elmworth gas field (Masters et al. 1984).
- The discovery well at Pecos Slope was originally drilled in 1951 for a deeper target and abandoned as a dry hole. In 1977 the same hole was opened again for an even deeper target, but again the result was disappointing.
- The discovery is attributed to the attention of a geologist, who noted some anomalies on the logs, interpreted as possible gas effect. The anomalies were visible through an 18 ft (5.5 m) thick sandstone interval of the Permian redbed sequence, uphole of the drilling objective. Many wells had been drilled through these redbeds before, but none of them ever tested any gas. The Permian redbeds were therefore classified as non-productive before the discovery at Pecos Slope. The geologist needed courage for trying to convince his superiors of spending money for running a drillstem test in an interval commonly noted as non-prospective!
- The geologist had incredible luck with that test: According to later experience, productive intervals at Pecos Slope normally don't produce prior to frac treatment! But fortunately, without any formation stimulation the first drillstem test flowed gas at a rate of 540 Mcf/d (15'300 cubic meters a day). A few months later, following acid and frac treatment, the flow increased to 2550 Mcf/d (72'200 m^3/d).
- Until 1990, a total of 864 wells was drilled. 764 of them went into production (Bentz 1992, p. 152) - a remarkable success rate in view of the complete lack of evidence for a structural closure!
- The productive sandstones at Pecos Slope display a typical feature on the logs: A *crossover between the neutron and density porosity logs* (the neutron porosity appears normally higher than the density porosity through wet intervals, but the dif-

ference reverses to lower values in pay zones). Note that the same kind of crossover with lower values for the neutron porosity is registered on logs recorded in Nagra's Weiach borehole. At Weiach, this phenomenon occurs within the following intervals: Triassic Buntsandstein (weakly expressed); Permian Rotliegend sandstones (strong), Carboniferous sandstones (sporadically). None of these intervals has been tested for hydrocarbons.

Attention: Normally, gas bearing sandstones are identified on logs by their increased electrical resistivity - except in some typical cases of nonconventional gas occurrences. There, the gross electric resistance of the formation may be masked by effects of the high content of connate water and clay minerals in micropores, resulting in a lower resistance. Cases of low resistivity gas reservoirs are particularly difficult to identify on logs.
Low resistivities, neutron log crossovers and microporosities agree well with observations on logs from the Permocarboniferous of Weiach. Such phenomena are well documented in Nagra's comprehensive reports from Weiach and also in reports of 1992 from Sneider to Swisspetrol.

The considerably larger net reservoir thickness at Weiach favourably compares to the just 9-24.4 m net in the Pecos Slope gas field. Accordingly, estimates of gas resources (gas-in-place) are high for the Weiach area, but require confirmation by extensive tests.
Coalbearing Permocarboniferous rocks of a similar setting as found at Weiach are expected to extend for at least 100 km^2 (24 700 acres) from the vicinity of Weiach. In addition, there are adjacent large areas with more deeply buried and probably thermally more mature coal beds along the axes of Paleozoic troughs, not accounted for in this context.

Taken the model of Pecos Slope, even non-structured shallow basin flanks and shoulders containing Permocarboniferous reservoirs could contain large hydrocarbon accumulations in traps of nonconventional type, due to capillary and porosity / permeability effects. The deeply buried trough axes could have generated huge volumes of gas, that migrated out towards the basin flanks and finally to the surface, charging stratigraphic traps on their way out or leaving residual gas accumulations behind. This opens up the possibility of the existence of trapping conditions similar to large producing gas fields in basin centered accumulations of the United States and Canada.

None of these potential trapping possibilities are tested. Questions to find out whether any of them could lead to commercial production, can only be answered by taking the risk and drilling new boreholes into the pre-Mesozoic at selected locations. These first steps have to be complemented by conclusive drillstem and production tests. Practical experience in drilling and testing the particularly delicate tight sandstone gas reservoirs can hardly be found in Europe. It requires the help of petroleum engineers from North America with the proper kind of experience.

Did Nagra core through a producible gas field without recognizing it?

The evidence of the Weiach corehole, in comparison to examples of the Pecos Slope and of other nonconventional gas finds in North America, make such a seemingly absurd situation perfectly possible!

References (with some annotations)

The present note is basically a rearranged extract of an internal memorandum, dated October 7, 1994, and addressed to the *Federal Nuclear Safety Inspectorate (HSK)*, an agency of the Swiss Government. As a consequence, this list of references is incomplete regarding later publications.

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