Geological model, advanced methods help unlock oil in Italy’s Apennines

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Tempa Rossa oil field is 50 km south of Potenza in the Basilicata region on the eastern side of the southern Apennine mountains at more than 1,000 m elevation.

It represents one of the most interesting oil fields discovered in the Apulian platform target beneath a regional thickness of allochthonous strata of 4,000 m.

Modern hydrocarbon exploration in the southern Apennines started during the late 1960s and resulted in small but significant oil fields in the following decade: Castelpagano with 31.1° gravity oil; Benevento with 46° gravity oil, and Pierre Mattavelli, 1986.

However, only a few companies were seriously involved in the exploration of the Campania-Lucania Apennines. This is due to poor quality seismic data, the depth of the expected reservoir, and major drilling difficulties related to the penetration of an overpressured allochthonous sequence before getting to the balanced or slightly overpressured target.

The small but encouraging AGIP Costa Molina oil field discovery (20.3° gravity oil) in 1982 only slightly increased the general interest for the region, which is inhibited by the relative high risk investments implied. Relevant improvement of seismic acquisition and processing techniques raised the interest of the area in the early 1980s. A small group of companies, especially FINA Italiana, Total, and AGIP concentrated the efforts in testing and evaluating all the more advanced exploration techniques available so as to
Exploration techniques

A careful geological analysis, integrated with a wide and updated knowledge of compressible belt case histories and structural, stratigraphic, and depositional models, is probably the major exploration technique for this area.

Southern Apennines seismic line interpretation, even if it is still the main tool, due to poor quality data is definitely insufficient for prospect evaluation if not driven by a predictive geologic model integrating all the available data.

Several papers dealing with southern Apennines structural and stratigraphic models have been published during the last few years, led the Laurentana license operator to generate its own general structural and stratigraphic model. Major efforts focused on establishing a qualitative stress regime model for the Apulian platform carbonates.

This work led through a new approach to the poor quality seismic data interpretation that resulted in the Tempe Rossa oil discovery within a previously explored area. Furthermore, this approach strongly enhanced the petroleum potential of previously neglected areas in this region.

Essential background references to our work include the already cited papers plus others.

Geological framework

The Southern Apennines fold-thrust belt resulted after the compressive deformation of the Tethys ocean southwestern margin during the Neogene convergence of the African and European plates.

From west to east, three major elements can be recognized within the Campania-Lucania sector: the Apenninic carbonate platform, the Lagonegro deep marine basin, and the Apulian carbonate platform.

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from overlying thrust stratata. Overthrust deep marine sediments (Ligurian units) bound westward Apenninic platform outcrops (Fig. 1).

Neogene emplacement of tectonic units marks the end of a story started in the early Mesozoic (Fig. 2). From the late Triassic up to the Neogene the paleogeography and the tectonic regime were monotonous; the Apenninic platform and the Apulian platform kept growing separated by the deep and starved Lagonegro basin (Fig. 2A).

The first relevant collisional phase could be attributed to the end of Neogene; Ligurian units overthrust Apenninic platform. The Apenninic platform is thrust over its eastern margin and the western sector of the Lagonegro basin. The resulting foredeep is filled by the "external flysch" strata (Fig. 2B). A further, probably more intense, compressive phase occurred at the end of the early Pliocene. The "external flysch," overlain by part of the Lagonegro basin, thrusts over the Pliocene foredeep, above the Apulian platform (Fig. 2C).

**Apulian platform foreland carbonates**

Inferred buried foreland structural style has to be related to the above mentioned tectonic phases. Compressive features along the Apulian platform western margin can be interpreted from the seismic lines, while within the eastern sector of the buried foreland and the Murge area outcrops extensional features occur.

Between these two zones a relatively deep belt is present. These subvertical reverse faults occur with major vertical displacement (several hundreds of meters), interpreted as "upthrust" or flower structure.

Based upon these observations, an eastward decreasing horizontal compressive stress axis similar to can be inferred within the Apulian platform (Fig. 3).

The western sector of Apulian platform, characterized by compressive features, could be interpreted as affected by a compressive regime with a horizontal northeast oriented \( \sigma_1 \) and vertical \( \sigma_3 \). Compressive stresses presumably dissipated along the western margin thrust faults.

Eastward of this compressive belt, a still horizontal, even though reduced with respect to the other stress axes, \( \sigma_1 \) can be inferred; \( \sigma_3 \) axis should therefore be horizontal and \( \sigma_2 \) vertical. A transpressive tectonic regime is therefore interpreted as responsible for the observed structural style.

Eventually, eastwest extensional regime with vertical \( \sigma_1 \) and horizontal \( \sigma_2 \) and \( \sigma_3 \) is probably a consequence of the peripheral bulge migration during the different tectonic phases.

Excellent reservoir properties of wrenching induced positive structures highlight, led by Harding,\(^{11}\) led us to concentrate our efforts toward this neglected main target. The Tempa Rossa 1D discovery, confirmed by Tempa Rossa 2 and Tempa Rossa 1D sidetrack, supported our model pointing out the potential of previously explored but underestimated areas.

**Well histories**

TR-1 directional was drilled as a deviated well due to terrain problems in siting a vertical location—at 5,080 m measured depth, through the allochthonous sequence and encountered about 700 m of oil bearing limestone of Tertiary and Cretaceous age.

Technological problems that occurred after the third drillstem test didn’t allow deepening or completion. A second well, TR-2, was planned by the same group of companies on the neighboring license of Torrente Sauru in 1991 about 3 km south of the discovery well.

During 1992 the TR-2, which penetrated an oil column of more than 800 m, was put on a 135 day extended well test and produced at a controlled natural flow rate approximately 1,220 b/d of oil with no water and no reduction of flow rate or wellhead pressure.

Following these very encouraging results, TR-1 directional well was reentered and sidetracked to 5,401 m in the limestone and dolomite from Miocene and Cretaceous age and tested 16-22° gravity oil over three intervals at flow rates of 1,600, 2,560, and 3,470 b/d.

**Tempa Rossa reservoir**

The unusually thick oil column and the various lithology and porosity types characterize this unconventional reservoir.

Modeling the Tempa Rossa reservoir is difficult due to fracture porosity not homogeneously distributed. After the section, microfracture and fissure, opened by horizontal borehole enlargement, and moldic and matrix porosity (especially in dolomite strata).

In order to get the best reservoir knowledge, efforts had been focused toward a high quality acquisition and elaboration of well site data. A special mud-logging unit was used, equipped with a small mud loss recording tool, a quantitative hydrocarbon occurrence indicator on the cuttings, the continuously recorded penetration rate was processed.
EXPLORATION

THE AUTHORS

Savoldo D'Auria has more than 10 years experience as explorationist and later chief geologist in SRB Exploration Mediterranean since 1968 before joining FINA Italia in 1982. He joined FINA as chief geologist and deputy exploration manager in 1974. He is currently project manager and exploration manager for FINA Exploration Lithia, where he is exploration manager and deputy general manager.

Roberto Pasi was formerly involved in academic research for neutronics national project. In May 1987, he joined AGIP SpA, where he worked as explorationist mainly devoted to prospect generation of Adriatic Sea gas and oil plays. He joined FINA Italia in 1984, where he dedicated his efforts mainly to regional studies and particularly gave his contribution to develop FINA's structural model of the southern Apennines as a seismic geologist, then as chief geologist, and from July 1992 as exploration manager of FINA Italia. He received a degree in geology from the University of Pavia, Italy.

Giosuè Bertozzi was involved in geological work in Mediterranean and later joined FINA Italia in 1963. He worked as a seismologist and later became a seismic supervisor. He is chief geologist in charge of reservoir evaluation and modeling of the Tompa Rossa complex including seismic and well test data. He has a degree in geology from the University of Pavia, Italy.

Paolo De Vito received a degree in geology from the University of Pavia. During 1985-86 he did undergraduate and graduate courses under Prof. F. Puglisi at the university and studied stratigraphy of Upper Cretaceous and Eocene strata of the southern Alps. In October 1988 he joined FINA, where he works today as expert in exploration and development of the Posidonia gas field in the Adriatic Sea. He has a degree in geology from the University of Pavia, Italy.

Conclusions

The modeling of the third dimension of the data, gathered in the few wells drilled, is therefore thought to be at this stage a risky task.

The history of fracturing assessment in situ, stress determination, diagenetic study will be performed to define a geological model that, supported by well test data, could reduce the risk of a statistical simulation.

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