7th Biennial International Conference & Exposition on Petroleum Geophysics

"HYDERABAD 2008"

P - 403

Shallow Evidences for Deeper Hydrocarbons –A Step towards Establishing Petroleum System

Shashirekha Mahapatra*, Duggirala Moses Nathaniel, Rabi Bastia, Srinivas Tenepalli, Ravi Verma
Petroleum Business (E&P), Reliance Industries Limited, India
e-mail*: Shashirekha.Mahapatra@ril.com*

Summary

Analysis of shallow seismic clues provides a framework to envisage deeper petroleum systems in frontier deepwater regimes. This exercise implemented for the Kerala-Konkan basin, evinced keen interest and permitted an understanding into possible deeper petroleum accumulations for the benefit of future exploration. They include pockmarks and carbonate mounds on the ocean floor, polygonal fault systems and features related to igneous intrusions.

Introduction

The elements of a petroleum system, such as presence of source and its characteristics, source maturity, migration, reservoir, trap and seal are essential to be understood for a successful exploration program. The rate and volume of hydrocarbon seepage modify the near surface geochemical, geophysical, geological and biological responses. Identification of such near surface and shallow-clues through multibeam and seismic may prove the existence of an active petroleum system and thus play an important role in frontier areas, such as deepwater Kerala-Konkan basin.

Petroleum seepages usually occur directly above or near the prospect and also at the end of migration pathways, upto tens or even hundreds of kilometers away. This means that both lateral and vertical migration aspects need to be assessed for an identified seepage to be linked to a possible prospect. Further, there is no way to estimate the commerciality of subsurface hydrocarbon accumulations based on the quantum of seeps, due to the strong influence of tectonics and the variety of different processes responsible for surface seeps. As a result, only some of them imply an underlying economic hydrocarbon accumulation.

Shallow clues: Seismic Expressions

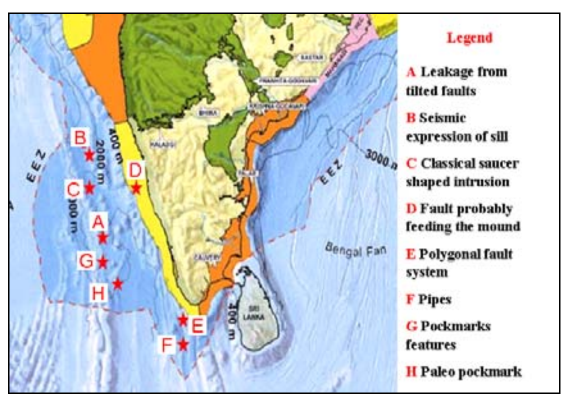

Fig. 1 Illustrating the location of examples described in the text from Kerala-konkan basin

Fig. 1 illustrates the locations, of shallow seismic expressions in Kerala-Konkan basin, discussed in the text along with respective analogues from petroliferous basins elsewhere. The pioneering works of many authors in this field is extensively quoted as a theoretical basis for this work.

Shallow Faults

Although small fractures are known to be important as potential hydrocarbon conduits (Smith, 1966), only seismically resolvable faults are taken in to account here as vertical fluid-migration pathways. The capacity of seismogenic faults to act as flow conduits needs to take into account, the slip behavior of the fault in addition to the static permeability of the fault zone. Considerable deviation of the efficiency of the conduit can be predicted for periods before, during, and immediately after active rupture of the fault plane, i.e., during the earthquake cycle. Faults most probably act as valves for fluids during active rupture events (Sibson, 1981; Muir Wood, 1994; Hickman et al., 1995 in Cartwright et al., 2007) and could potentially bleed away large volumes of fluid from a reservoir in contact with the active fault. (Fig. 2)

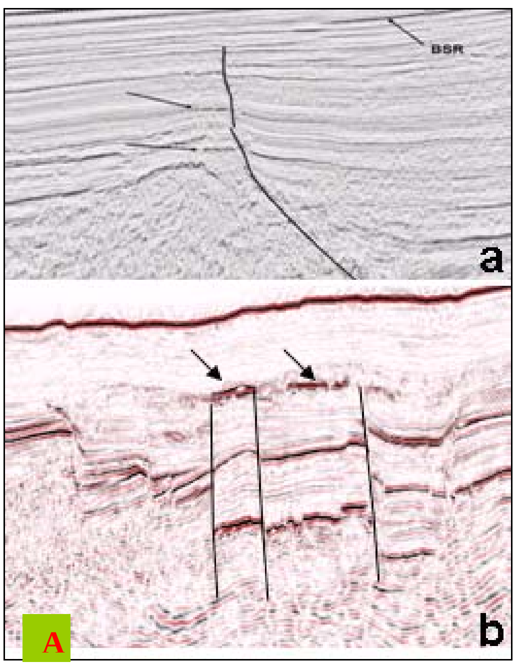

Fig. 2 (a) Leakage from the crestal region of a large tilted fault block expressed as vertically distributed amplitude anomalies (arrowed) in the footwall to this major trap defining fault (Cartwright et al., 2007) (b) Possible leakage from tilted fault blocks, expressed as bright amplitude (arrowed) – from Kerala - Konkan basin.

Igneous Intrusions

In case of igneous intrusions, the hot magma (>1000°C) intrudes into wet and cold sediments, where they induce major changes in the host rock properties for tens of meters away from the immediate contact zone. In addition to fracturing associated with forceful intrusion, fracture-sets also form during prograded metamorphism in the contact aureole and also in the thermal contraction fracturing during longer term cooling of the intrusive body itself. These different fracture sets thus provide a fracture permeability network at various scales surrounding the intrusion and occasionally within the body of the intrusion itself (Einsele et al., 1980). As exploration campaigns are booming in volcanic continental margins such as West Africa, India, Brazil and northeast Atlantic margin deepwater, it will become an essential part of exploration to recognize which igneous intrusions act as major fluid-flow conduits (Fig. 3).

Classical saucer shaped intrusions are found at shallow depths in undeformed basin settings in the NE Atlantic, NW Australia and Karoo basins. The sizes of the saucers increase with increasing emplacement depth. Emplacement of magmatic intrusions will lead to heating of pore fluids and metamorphic reactions, possibly causing an explosive rise of fluids and fluidized sediments to the surface and thus forming hydrothermal vent complexes, which are favorable for secondary petroleum migration and seeps (Planke et al., 2003). Refer Fig. 4.

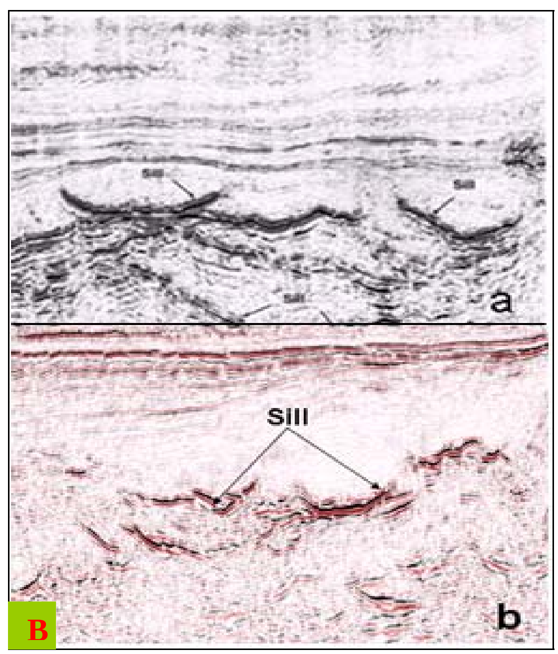

Fig. 3 (a) Seismic expression of major igneous sills from the Rockall Basin, offshore United Kingdom (Cartwright et al., 2007). (b) Seismic expression of major igneous sills - from Kerala-Konkan Basin.

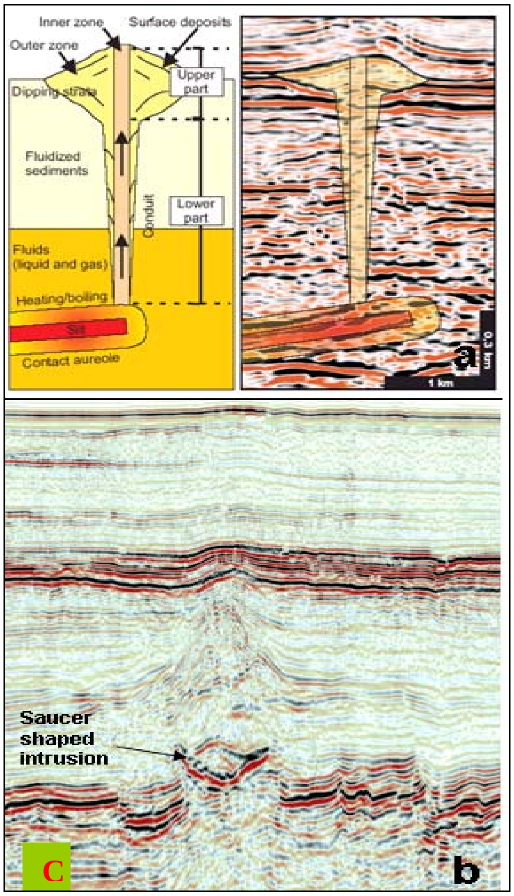

Fig. 4 (a) Nomenclature and seismic example of a hydrothermal vent complex (Planke et al., 2003). (b) Similar saucer shaped intrusion (sill) - from Kerala-Konkan basin.

Carbonate Mound

In Area D (Fig. 1), the multibeam data shows a mound ~20 m tall and 2 km across, lying on a fault trend (Fig. 5a) in a water depth of 100m. The mounds and buildups along fractures have very high backscatter values suggesting that they are composed of some hard material, probably carbonates. Buildups, parallel to the main fault trend are due to organisms feeding on the fluids seeping from subsurface. A fault to the west of the mound, related to a deeper compressive structure is seen in Figure 5b. It is thought that fluids from deep in the section migrated through these faults and led to carbonate deposition on the seafloor.

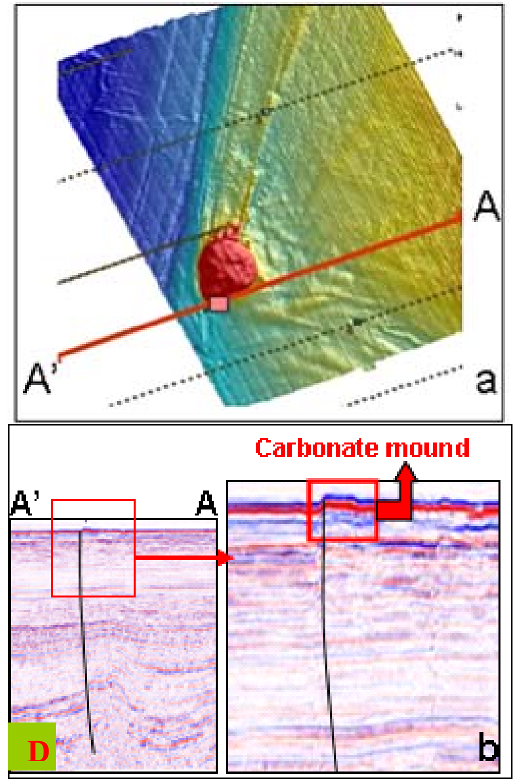

Fig. 5 (a) Multibeam data shows a mound of ~ 20 m tall and 2 km lying on a fault trend. (b) A fault probably feeding the mound in the Kerala-Konkan basin.

Polygonal faults

Polygonal faults are generally seen within certain fine-grained lithologies, such as smectitic clay stones and calcareous or siliceous oozes. Sealing sequences of Eocene age in the North Sea are deformed by extensive polygonal fault systems and yet overlie many prolific Paleocene reservoirs, suggesting that these faults do not compromise the seal integrity. Indirect indicators for fluid flow along polygonal faults have been inferred from pockmark trails, etc. that are observed above polygonal faults in diverse settings (Gay et al., 2004). In the Ormen Lange field gas leakage from hydrocarbon reservoirs has also been indirectly linked to polygonal faults where these faults are acting as the main conduits (Stuevold et al., 2003; Berndt et al., 2003). In summary, polygonal faults, act as a seal for many prolific accumulations due to the insufficient fluid flow to breach the seal and their occurrence predominantly in low permeability sediments. However, these faults may be reactivated by certain conditions and act as conduits (Cartwright et al., 2007). Refer Fig. 6 &7.

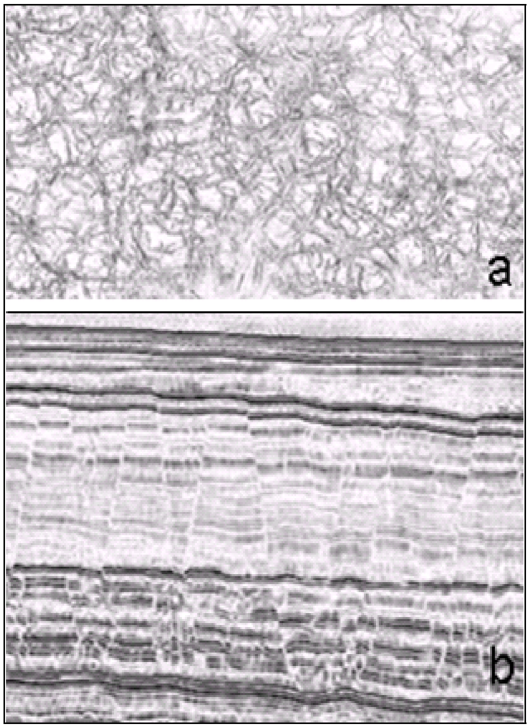

Fig.6 (a) Horizontal slice through a variance attribute volume showing a classical polygonal network, (b) Seismic expression of polygonal fault system (Cartwright et al., 2007).

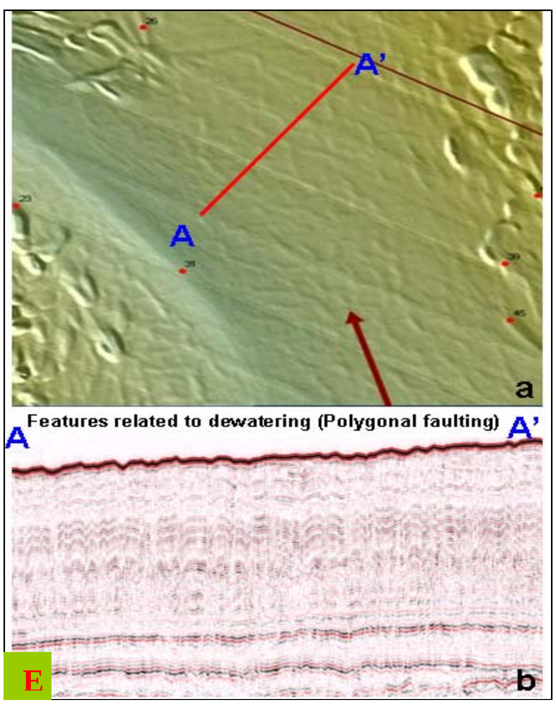

Fig. 7 (a) Polygonal fault in multibeam data (in Kerala-Konkan Basin) (b) seismic expression of polygonal fault systems (similar to Fig. 6b).

Pipes

Seismically pipes are defined as columnar zones of disturbed reflections that may or may not be linked with sub vertically stacked amplitude anomalies. As they tend to exhibit a vertical to sub vertical geometry, they tend to be confused with seismic artifacts such as scattering artifacts, migration anomalies, lateral velocity anomalies, and attenuation artifacts related to shallow diffractors. Hence pipes are commonly ignored on seismic data (Løseth et al., 2001, 2003; Davies, 2003).These typical seismic signatures should be differentiated from seismic artifacts with proper attention. They are usually seen to emanate from crestal regions, e.g., tilted fault block crests, fold crests, or crests of sand bodies with positive topography, but some are also documented from flat-lying units or synclinal regions (Fig. 8).

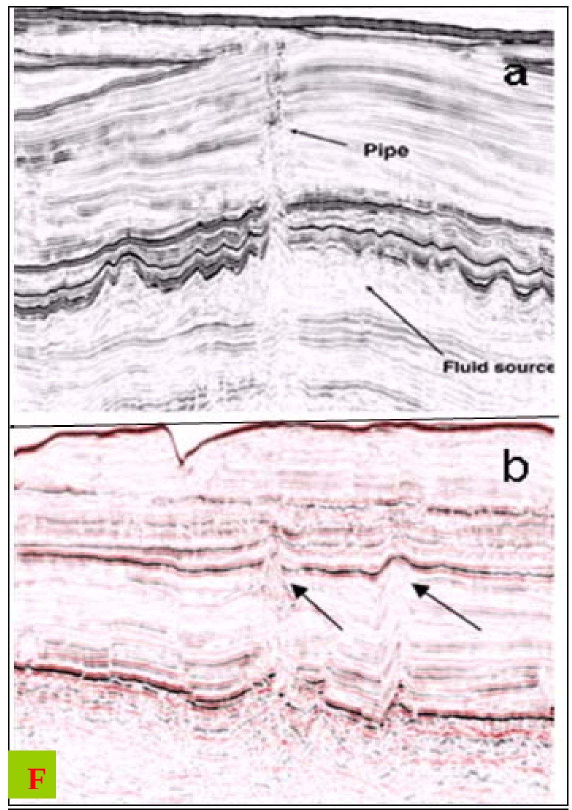

Fig. 8 (a) A large pipe from the Faeroe-Shetland Basin, offshore United Kingdom (Cartwright et al., 2007). (b) Large pipes - from Kerala-Konkan Basin (arrowed)

Pockmarks

Cone-shaped circular or elliptical depressions named pockmarks, generally appear in unconsolidated fine grained sediments, and are very good indicators of hydrocarbon release. Due to the accumulation of free gas, excess pore fluid pressure may be generated, leading to the release of fluids along faults in the highly faulted interval, forming pockmarks at the seafloor (Gay et al., 2006). Pockmarks are visible on the multibeam data as well as seismic sections (Fig. 9). Also many paleo-pockmark features have been identified, indicating release of fluids at the paleo-seabed.

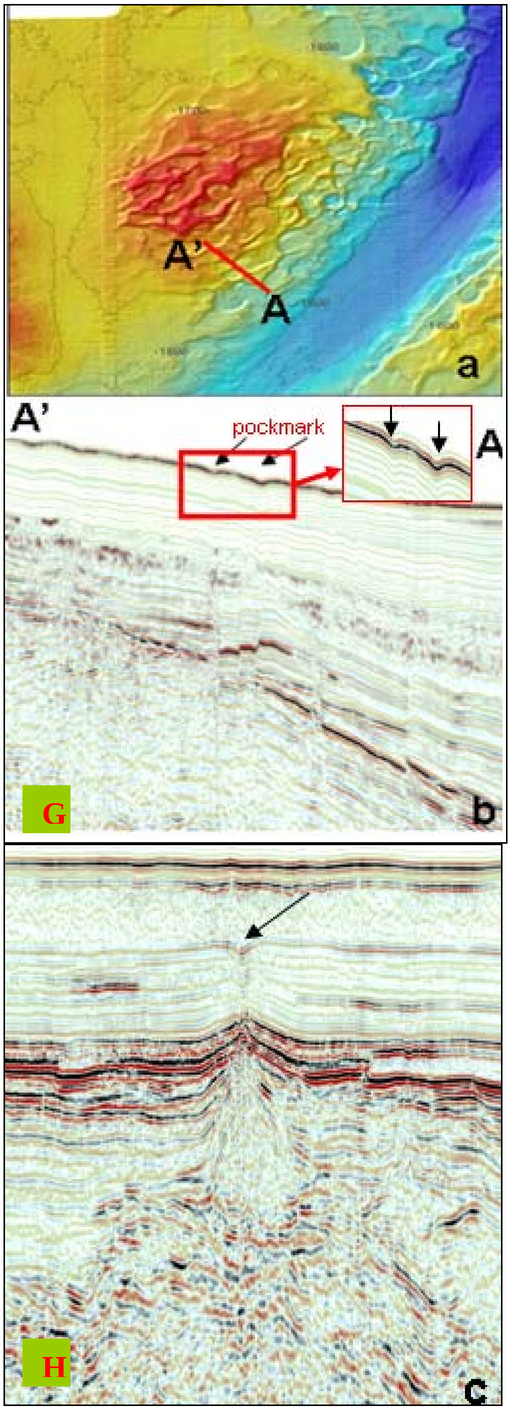

Fig. 9 (a) Multibeam data showing pockmark features on the sea bed in the Kerala-Konkan basin. (b) A seismic section showing pockmark (arrowed). (c) Seismic section showing a paleo-pockmark (arrowed).

Conclusion

Shallow seismic clues in conjunction with multibeam data helped in the identification of features related to fluid escape like polygonal faults, pipes, pockmarks, mounds, permeable igneous intrusions which may have acted as conduits for hydrocarbon fluid migration. These features indicate the presence of a mature source and an active petroleum system in the Kerala-Konkan basin. However, it must be stressed that while identification of these features supports the presence of petroleum system, their absence doesn't disprove the same.

Acknowledgements

The authors would like to express their gratitude to Reliance Industries Ltd. for supporting the publication of this work. We thank our colleagues for discussions and advice. Also thankful to Dan Orange for his insists in multibeam data.

References

Berndt, C., Bunz, S., and Mienert, J., 2003, Fluid expulsion from polygonally faulted clays, Norwegian margin, in Rensbergen, P. V., Hillis, R., Maltman, A., and Morley, C., eds., Subsurface sediment mobilisation: Geological Society (London) Special Publication 216, p. 223–243.

Cartwright, J., Huuse, M., and Aplin, A., 2007, Seal bypass systems, AAPG Bulletin.

Davies, R. J., 2003, Kilometer-scale fluidization structures formed during early burial of a deepwater slope channel on the Niger Delta: Geology, v. 31, p. 949– 952.

Einsele, G., Gieskes, J. M., Curray, J., and Moore, D.M., 1980, Intrusion of basaltic sills into highly porous sediments, and resulting hydrothermal activity: Nature, v. 283, p. 441– 445.

Gay, A., Lopez, M., Cochonat, P., and Sermondadaz, G., 2004, Polygonal fault-furrows system related to early stages of compaction, upper Miocene to present sediments of the lower Congo Basin: Basin Research, v. 16, p. 101–116.

Gay, A., Lopez, M., Cochonat, P., Séranne, M., Levaché, D., and Sermondadaz, G., 2006, Isolated seafloor pockmarks linked to BSRs, fluid chimneys, polygonal faults and stacked Oligocene–Miocene turbiditic palaeochannels in the Lower Congo Basin.

Hickman, S., Sibson, R., and Bruhn, R., 1995, Introduction to special section: Mechanical involvement of fluids in faulting: Journal of Geophysical Research, v. 100, p. 12,831– 12,840.

Løseth, H., Wensaas, L., Arntsen, B., Hanken, N., Basire, C., and Graue, K., 2001, 1000 m long gas blow- out pipes: 63rd European Association of Geoscientists and Engineers Conference and Exhibition, Amsterdam, Extended Abstracts, p. 524.

Løseth, H., Wensaas, L., Arntsen, B., and Hovland, M., 2003, Gas and fluid injection triggering shallow mud mobilization in the Hordaland Group, North Sea, in Rensbergen, P.V., Hillis, R., Maltman, A., and Morley, C., eds., Subsurface sediment mobilization: Geological Society (London) Special Publication 216, p. 139–157.

Muir Wood, R., 1994, Earthquakes, strain cycling and the mobilisation of fluids, in Parnell, J., ed., Geofluids: Geological Society (London) Special Publication 78, p. 85–98.

Planke, S., Jamtveit, B., Malthe-Sørenssen, A., Myklebust, R., Svensen, H., Rasmussen, T., Rey, S. S., and Berndt, C., 2003, Volcanic Processes and Deposits on Rifted Margins and in Sedimentary Basins, Extended Abstract - Rio2003.

Rensbergen, P.V., Hillis, R., Maltman, A., and Morley, C., eds., 2003 subsurface sediment mobilisation: Geological Society (London) Special Publication 216, p. 263– 282.

Sibson, R.H., 1981, Fluid flow accompanying faulting, field evidence and models, in Simpson, D.W., and Richards, P.G., eds., Earthquake prediction an international review: American Geophysical Union Maurice Ewing Series,v.4,p.593-603.

Smith, D.A., 1966, Theoretical considerations of sealing and non-sealing faults: AAPG Bulletin, v.50, p.363-374.

Stuevold, L., Faerseth, R., Arnsen, L., Cartwright, J. A., and Moller, N., 2003, Polygonal faults in the Ormen Lange field, offshore Norway.