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Mannar Volcanics - Implications for Madagascar Breakup

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Summary

Mannar sub basin of Cauvery basin is the southern- most of the Mesozoic rift basins existing along eastern continental margin of India and lies between Indian coast and Sri Lanka. The volcanic activities within Turonian sediments so typical of Gulf of Mannar are seen in almost all the drilled wells but have not been reported from any of the other sub basins of Cauvery basin. This is also reported in Pearl-1 well of Mannar sub basin in Sri Lankan offshore. Taking clue from the pattern of reflectors corresponding to intrusions, seismic study has been extended to the deeper part of Gulf of Mannar and also in its western part (towards Comorin ridge side) and observed the spread of this igneous activity which covers quite a large area. Recent dating through ^{40}Ar-^{39}Ar studies carried out on one core sample of drilled well GM-E-A is around 89.1+0.65 Ma (Rathore et al., 2007). This age of the intrusive matches excellently with radiometric age for the Madagascar flood basalt province, the felsic volcanics of St Mary's Island (SMI), two late Cretaceous mafic dykes around Huliyardurga, Karnataka and two regional dykes from Kerala region of South-western India. Together, therefore, the volcanic activities around these places may be associated with the break up of Greater India (India plus Seychelles) and Madagascar, envisaged to have occurred in Upper Cretaceous at ≈88Ma.

Introduction

Initial rifting in the Cauvery basin took place during Lower Mid-Cretaceous (Pre-Albian and Albian) and led to the establishment of NNE-SSW trending horst-graben. Gulf of Mannar sub basin appears to be devoid of the influence of these structural lineaments for the most part except in the northeastern section. The horst and graben tectonics, so characteristic of the Cauvery Basin is absent in Gulf of Mannar and the entire basin had remained a broad graben all through its history between the outcropping Sri Lanka and Indian peninsular massifs.

Curray (1984) opined that the first rifting between India, Sri Lanka and Antarctica occurred through the Cauvery- Palk Strait – Gulf of Mannar zone but this rift did not progress into the sea floor spreading stage. Instead, the break occurred between Sri Lanka and Antarctica, as a result the Cauvery – Palk Strait –Gulf of Mannar Basin became a failed rift or aulacogen dating from the Late Jurassic/ Early Cretaceous. In Gulf of Mannar area, approx 190km long NE-SW trending tectonic feature ('A' on Fig. 1) has been inferred from satellite derived gravity mosaic. This linear feature joins two approx NNE-SSW trending linear gravity lows, one off southern tip of India, and the other sub-parallel to the west coast of Sri Lanka ('B' and 'C'). According to Desa et.al. (2006), these two strong gravity lows may either represent the transform ridges or the continent-ocean boundaries of India and Sri Lanka respectively. Further, a NE-SW trending median high divides Indian part of Gulf of Mannar into two lows- a shallower northern low and a deeper southern low.

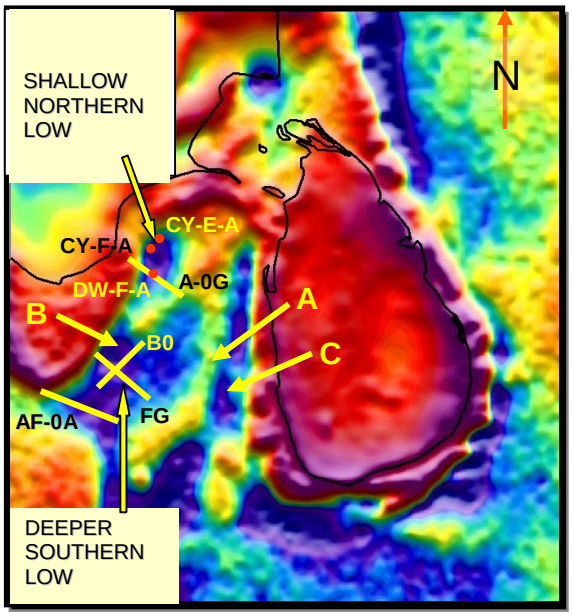

Fig.1 Satellite Gravity map showing tectonic features of Gulf of Mannar

It appears that during the beginning of the Late Cretaceous, active tectonism was prevalent in the Cauvery Basin with subsidence all over the basin. This was accompanied by extensive lava flows and igneous activity. Six off shore wells namely M-A-A, GM-A-A, GM-D-A, GM-E-A, GM-F-A and DW-F-A were drilled mainly in the northern low area, all the well encountered dolerite except one well (confirmed through cuttings and cores). Intrusives (sometime in phases as encountered in the well GM-F-A), mainly confined within the Turonian sediments. This Turonian age has been established through biostratigraphy, as the sediments of Albian age characterized by Hedbergella planispara, Ticinella sp., Globigerinelloides sp etc. occur below the intrusives and sediments of Coniacian age characterised by Hormosina ovulam, Saccammina, Trochammina sp., occur above this intrusive This igneous activity is also reported in well Pearl-1 in the Sri Lankan side of Mannar sub basin. On logs, these intrusives showed low gamma and very high resistivity and low values of ΔT (Fig. 2).

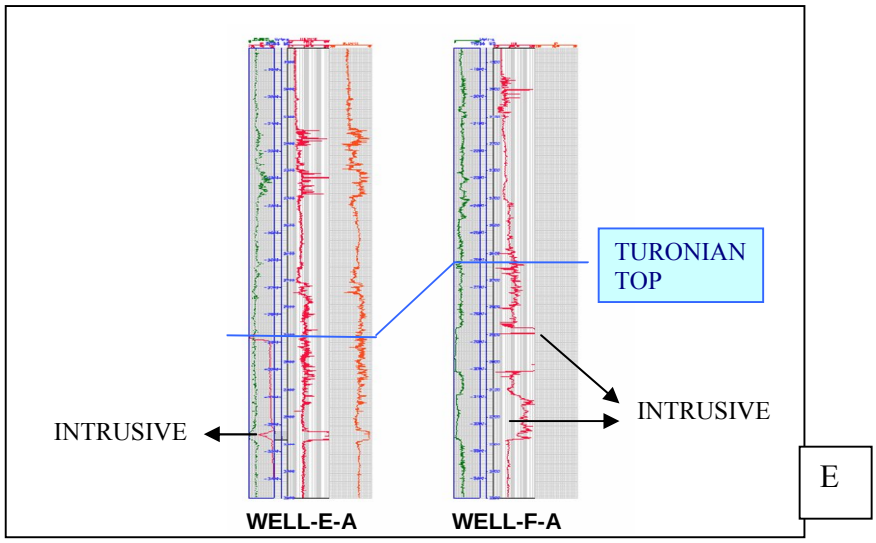

Fig.2 Log impression of the intrusive in the drilled wells

Tying in seismic section, it corresponds to a typical high amplitude reflector (Fig. 3). Relying on indirect method of seismic imaging and taking clue from the pattern of reflectors corresponding to intrusions, we have extended the seismic profiling in the deeper part of Gulf of Mannar and also in its western part (towards Cameroon ridge side) and felt the presence of these igneous activity over a considerable part. (Figs. 4, 5 & 6). This event sometimes exihibits a convex upward curvature (Fig.5). Although it has been known for a long time that the localized syn-rift

volcanism often accompanied the break up of the continents, but it has also been realized that some margins exhibit very considerable igneous activity (Hinz,1981; Robert,1984;White 1987,1988). Volcanic flow, dipping reflectors by contrast, generally exihibit convex upward curvature with dips (Fig. 5) that increases in a sea ward direction. (White et al.,1989).

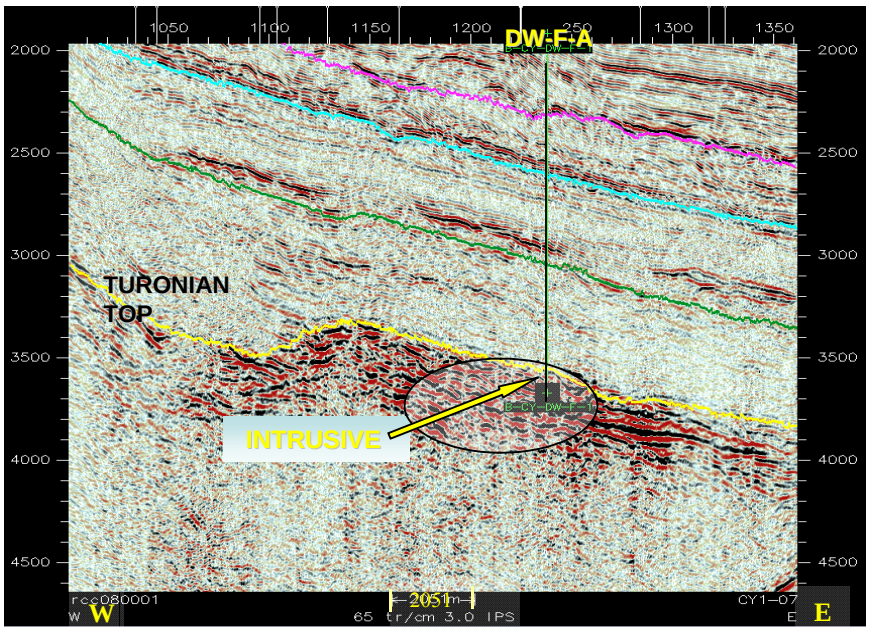

Fig.3 Seismic line (CY-A-0G) passing through well DW-F-A showing the intrusive

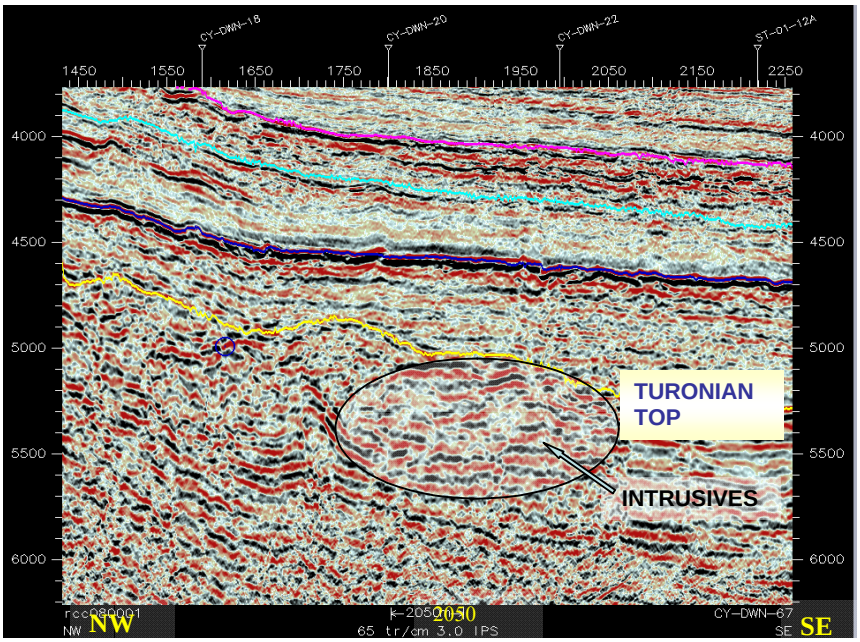

Fig.4 Seismic section showing (DWN-FG) reflection pattern of intrusives

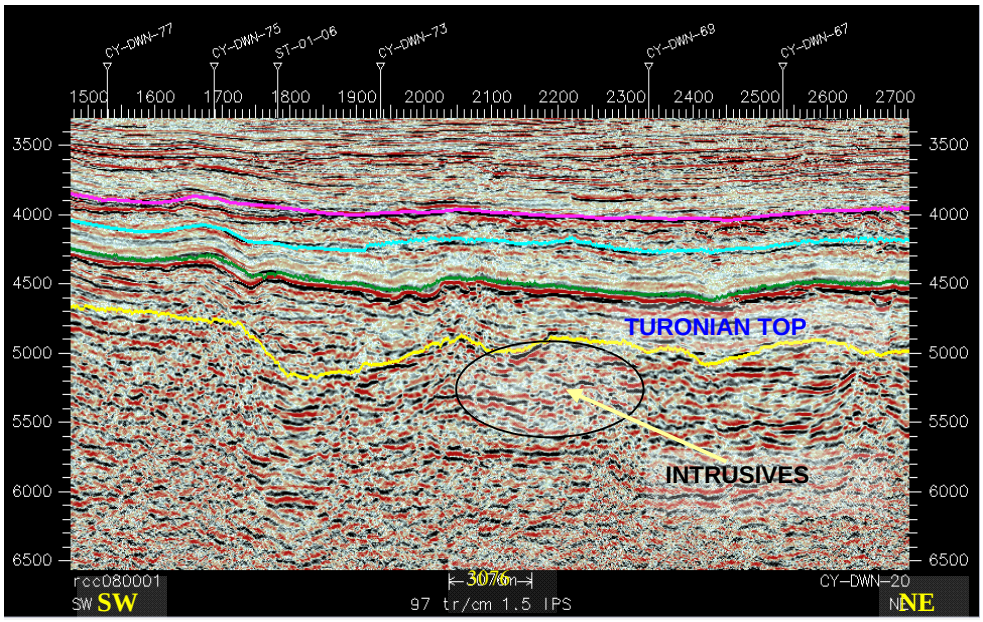

Fig.5 Seismic section (DW-B0) showing reflection pattern of intrusives in the deeper southern part

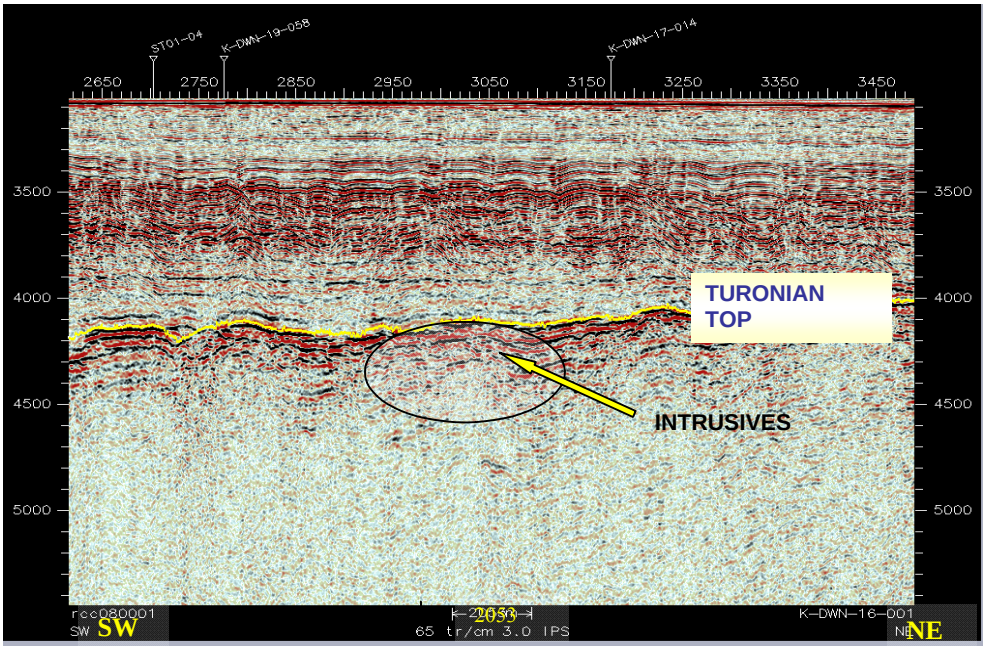

Fig.6 Seismic section (K-AF-0A) showing reflection pattern of intrusives in the western part

Discussion

The felsic volcanics (rhyolite and rhyodacite) of the St Mary's Island (SMI, a group of four main islands, about 6 km west of Udupi town in coastal Karnataka state) were dated earlier around 93Ma by K-Ar technique and later on 85.6=0.9 Ma by ^{40}Ar-^{39}Ar technique. This age of SMI volcanics corresponds excellently with ^{40}Ar-^{39}Ar ages of ≈ 89 to 85Ma for the Madagascar flood basalt province. (Pande et al., 2001). The Greater India –Madagascar break up considered to be related to Marion hot spot was accompanied by the formation of an extensive volcanic province in Madagascar, specially along its rifted Eastern margin, comprising voluminous flood basalt flows and dolerite dykes with subordinate rhyolite flows. Seventeen ^{40}Ar-^{39}Ar age determinations reveal that volcanic rocks and dykes from the 1500km long rifted eastern margin of Madagascar were emplaced rapidly (mean age ≈ 87.6 ± 0.6Ma). The evidence suggests that the thick lava pile at Volcan de l'Androy in the south of the island marks the focal point of the Marion hot spot at ≈ 88 million years ago and that this mantle plume was instrumental in causing continental breakup. (Storey et al.,1995).

Though counterpart volcanic activity on the Indian side has not been umambiguously identified so far, two late Cretaceous mafic dykes with an ENE strike that is orthogonal to the west coast of India and located nearly 200km inland around Huliyardurga, Karnataka state, yield ^{40}Ar-^{39}Ar plateau ages of 90.0±1.0. These Fe-Ti enriched tholeiites are essentially co-eval with at least three other igneous suites widely scattered in southern India, namely, the leucogabbro dyke of central Kerala and felsic dyke (both dated ≈85Ma through K-Ar technique) of north Kerala, the Agali-Anaikatti dykes (80 to 90Ma) of central Kerala-Tamil Nadu (Kumar et al.,2001; Pande et al.,2001; Radhakrishna et al., 1999).

In Mannar sub basin, in well GM-E-A, one core sample of the intrusive (depth 3242m) was studied under thin section and the rock appears to be medium to coarse grained igneous rock showing presence of plagioclase feldspar, pyroxenes and iron ore minerals i.e magnetite. Based on the petrography, the rock is classified Dolerite. Geochronological studies carried out on the sample by ^{40}Ar-^{39}Ar technique have dated it ≈89.1±0.65Ma which is interpreted to mark the upper limit to the time of dolelitic intrusive activity in this area. Also the ^{87} Sr/^{86}Sr ratios of the dolerite intrusives from well GM-E-A and GM-F-A range between 0.704194-0.704801 which suggests a depleted mantle source of the magma. (Rathore et al.,2007). So, the possible emplacement age of dolerite from GM-E-A and its spread over the Gulf of Mannar and adjoining area, coincides with the tectonic event activity which apparently took place in south western coast of India, Dharwar craton, St Mary's Island as well as eastern coast of Madagascar. It is envisaged that all these volcanic activities are related to break up of Greater India (India plus Seychelles) and Madagascar and have occurred in the beginning of Upper Cretaceous at around 88Ma.

Conclusion

Gulf of Mannar, the southernmost sub basin of Cauvery basin remained a broad graben all through its history between the outcropping Sri Lanka and Indian peninsular massifs. Volcanic activity is reported in almost all the wells (mainly in the northern shallower low) as well in Pearl-1 well in the Sri Lankan part of Mannar sub basin. The spread of this volcanic activity is tracked in the southern deeper part as well western part (near Cameroon ridge) of the area through reflection pattern /seismic profiling.

Geochronological dating through ^{40}Ar-^{39}Ar studies carried out on one core sample of drilled well GM-E-A is 89.1 ±0.65Ma. This age of the intrusive matches excellently with for the Madagascar flood basalt province, the felsic volcanics of St Mary's Island (SMI), two late Cretaceous mafic dykes around Huliyardurga, Karnataka and two regional dykes (a leucogabbro and a felsite) from Kerala region of South-western India. The volcanic activities around these places may be associated with the break up of Greater India (India plus Seychelles) and Madagascar and to have occurred in Upper Cretaceous at ≈ 88Ma.

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