SEDIMENTARY STRUCTURES OF THE TERTIARY ROCKS AROUND TARAKESHWAR, DISTRICT SURAT, GUJARAT AND THEIR DIAGENETIC SIGNIFICANCE

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Abstract
Tertiary rocks are exposed around Tarakeshwar, Surat district, Gujarat. These are mainly Eocene sediments which are predominantly clastic and are overlain by carbonate sediments. Several interesting sedimentary structures are revealed by calcareous claystones associated with fossiliferous limestones; among them concretions, septarian nodules and imatra stones are striking. These secondary sedimentary structures are developed due to chemical changes effected during diagenesis of the fine grained detrital sediments, probably involving precipitation of calcium carbonate in the pores of silt beds. The sediments were deposited in a near-shore environment of a shallow Eocene sea.

Introduction
Tertiary sedimentary rocks are exposed near Tarakeshwar, Surat district, Gujarat (Fig. 1). Sediments of this area assume importance because their equivalents are found to be oil-bearing in the Ankleshwar oilfield located about 35 km west.
Occurrence of Tertiary rocks in this area was reported by Blanford (1869), wherein he made a special mention of fossiliferous limestones. Rao (1941) surveyed the area around Tarakeshwar, Ghola and Kimamlee and described the foraminifers found in the limestones, such as nummulites, pellatispira, lepidocyclina and disco-cyclina, which are characteristic of Ranikot rocks belonging to the Eocene period. Gadekar (1977, 1980) has been studying the Tertiary rocks in the adjacent Jhagadia area with special reference to stratigraphy and sedimentation. An account of the sedimentary structures in the rocks around Tarakeshwar is presented in this paper.

Geology

About 600 m of Tertiary rocks overlie the Cretaceous Paleocene Deccan Trap basalts near Tarakeshwar. In accordance with the International Guide to Stratigraphic Classification, Terminology and Usage (1972), these rocks have been designated by the author as ‘Surat Group’. This Group is, in turn, divided into Tarakeshwar and Munjalao Formations. Generalised stratigraphy of the area is presented in Table I. The sediments are both clastic and non-clastic consisting of

<table>
<thead>
<tr>
<th>Stratigraphic units</th>
<th>Rock stratigraphic unit</th>
<th>Approximate maximum thickness mts</th>
<th>Gross lithology</th>
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<tbody>
<tr>
<td></td>
<td></td>
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<td>Alluvium. Yellow to brown clays, silts with kankar. Black cotton soil.</td>
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<tr>
<td>Deccan</td>
<td></td>
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<td>Thin bands of lenticular violet tuffaceous beds. Dark gray to black Deccan Trap basalts, hard, compact, fine grained, vesicular and amygdaloidal, jointed and exfoliated.</td>
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<tr>
<td>Eocene</td>
<td>Surat</td>
<td>200</td>
<td>Tarakeshwar</td>
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<td></td>
<td>Munjalao</td>
<td>400</td>
<td>Munjalao</td>
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<tr>
<td>Paleocene to Upper</td>
<td>Deccan</td>
<td>Indeterminate</td>
<td>Detrimentate</td>
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<td>Cretaceous</td>
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The stratigraphic units met with in the area are:

**Deccan Trap:** The rocks belonging to this unit are mainly basalts. They are exposed beyond Usked Ramkund, west of Tarakeshwar; around Dungari in north and around Bodhan in south. The rock is dark gray to black in colour, hard,
compact, fine-grained, occasionally porphyritic, with laths of plagioclase as phenocrysts. Vesicular and amygdaloidal textures are also seen. Amygdales are usually filled with quartz, silica and zeolites. Veins of secondary minerals like quartz and calcite are often found criss-crossing basalts. Outcrops show exfoliation. These volcanic rocks are locally overlain by small patches of red, brown and yellow tuffaceous beds.

**Munjalao Formation:** Deccan Trap basalts are unconformably overlain by a thick succession consisting of alternations of yellow-brown claystones, variegated clays and light bentonitic clays with thin bands of red brown ferruginous sandstones. The formation shows considerable variation in lithological characters. The claystones are occasionally fossiliferous containing foraminifers (nummulites) and gastropods. The rocks have developed lateritic crust near Nani Naroli. At places, small lenses of conglomerates containing pebbles of agate, jasper and trap are found associated with claystones.

**Tarakeshwar Formation:** This unit consists of yellow to reddish brown limestones, very fine-grained, compact and are highly fossiliferous. They are nummulite-bearing. This formation is a type section for nummulitic limestones. Other fossils include lamellibranchs, gastropods and brachiopods; sometimes skeletal fragments like teeth of fish are also found. On the basis of its fine-grained and fossiliferous character, the rock is termed as biomicrite. The sediments show characteristic honey comb weathering pattern. Based on their fossil content, the rocks have been assigned upper Eocene age (Priabonian) by Rao (1941).

**Alluvium:** The Tertiary rocks of the area are covered by Quaternary alluvium composed of yellow silts, clays intercalated with kankar. Black cotton soil is encountered in the eastern part.

**Sedimentary structures**

Sedimentary structures of secondary category of Pettijohn (1975) are observed in the study area. Carbonate concretions and nodules are found in the lower part of the Tarakeshwar Formation near Charetha. These concretions are of two types: (a) septarian nodules (Fig. 2), and (b) imatra stones (Fig. 3).

a) **Septarian nodules:** These are found enclosed in calcareous claystones. They are oval and spheroidal, with diameters varying from 10-15 cm. The broken nodules show internal structures, such as radiating cracks that widen towards centre and die out towards periphery. These cracks, in turn, are traversed by a series of concentric cracks; they appear polygonal near margin but seem radial throughout. They show layered arrangement. Outermost layer is yellow, whereas inner one is brown. The central portion is filled with small shining euhedral crystals of calcite.

**EXPLANATION OF FIGURES**

Fig. 2. Septarian nodule from calcareous claystone, Tarakeshwar Formation, Charetha, near Tarakeshwar, showing internal structure comprising radiating cracks.

Fig. 3. Imatra stone from calcareous claystones, Tarakeshwar Formation, Charetha, near Tarakeshwar. Spherical nodule shows rounded mamillary projections on flattened edges.
Layered arrangement and crystalline core resemble geodes in Deccan Trap containing cryptocrystalline and crystalline silica.

b) **Imatra stones**: These are similar in mode of occurrence to septarian nodules described above. They are oval in shape and resemble flattened and compressed spheres. Longer axes of these bodies measure 10-15 cm. The flattened edges of these nodules show rounded mammillary projections. The colour is light to dark brown. Concretions are highly calcareous. The surface of nodules is covered with very thin hair-like polygonal cracks, each about 1 cm in length. The longer axis of the nodules is parallel to bedding of the enclosing calcareous claystones.

**Discussion**

Carbonate concretions are formed by precipitation with or segregation of mineral matter penecontemporaneous with or subsequent to sedimentation. Raiswell (1971) has shown that such concretions help in understanding the nature and sequence of diagenetic processes. The concretions contain a record of the environment which prevailed at the time of deposition.

The origin of a septarian nodule involves formation of a body when the exterior was hardening and the interior was subjected to dehydration and generation of shrinkage crack pattern, followed by filling with precipitated calcite crystals, resulting in development of network of veins. This characteristic structure is believed to have been formed from a highly porous water-laden sediment. The cracks developed in septarian nodules are due to synaeresis (Collinson and Thompson, 1982). This phenomenon suggests subaqueous shrinkage and may result from rapid flocculation of clay layer accentuated by compaction (Reineck and Singh, 1980). Increase in the salinity of argillaceous water-laden layer may result in the development of synaeresis cracks. This process is generally operative in coastal lagoons and inland sabkhas.

Imatra stones have been reported from glacial clays. They are also termed as marlekors (Tarr, 1935). Their occurrence in non-glacial silty calcareous clays of the Tarakeshwar Formation is therefore noteworthy. These concretions are presumably formed as a result of localised precipitation of calcium carbonate in the pores of silt beds.

The presence of synaeresis cracks on the surface of the nodules is very interesting and is suggestive, like those of the septarian nodules referred to above, of subaqueous shrinkage aided by compaction. The pore water in clays was expelled by compaction. Subsequent changes led to the development of concretions (Potter et al. 1980).

Concretionary structures are helpful in understanding depositional and diagenetic environments of the Tarakeshwar Formation. As a matter of fact, considering their characters, lithology of the host rocks, palaeontologic and mineral assemblages of the Surat Group of rocks, and field relationships, the geologic history of the area is reconstructed as follows:

a) Subaerial volcanic activity of fissure type in upper Cretaceous to Paleocene times, when stupendous amount of basaltic lava (Deccan Trap) was poured out. Towards its close, the activity was explosive as suggested by the presence of tuffaceous beds overlying traps near Usked Ramkund, southeast of Tarakeshwar.

b) Development of laterite by subaerial weathering of basalts under tropical monsoon type of climate, probably during Paleocene and early Eocene. There were brief incursions of shallow sea when fossiliferous claystones were deposited.
Ferruginous sandstones suggest local transitional, probably deltaic sedimentation. Subaerial weathering of basalts yielded agate pebbles which on consolidation in ferruginous matrix gave rise to lenses of agate conglomerates. Alteration of volcanic ash developed bentonitic clays. This period of subaerial weathering and sedimentation under alternate continental and transitional environments continued uninterrupted throughout early Eocene period during which the Manjalao Formation was deposited.

c) The upper Eocene (Priobonian) period witnessed marine incursion during which the Tarakeshwar Formation was laid. Shallow sea occupied the entire area. In this littoral to sublittoral environment abundant organisms like nummulites, lamellibranchs, gastropods and brachiopods flourished. This period marked carbonate sedimentation, both from organic and chemical sources.

d) Diagenetic environment set in during post-Eocene period. Highly laden calcareous and silty clays in the lower Tarakeshwar Formation were subjected to compaction. Subaqueous shrinkage gave rise to synaeresis cracks as a result of expulsion of pore water. Concretions like septarian nodules, imatra stones were developed. Calcium carbonate was precipitated in the final stages of diagenesis giving rise to layers of tiny euhedral calcite crystals in the centre of the cracks.

e) During the subsequent post-Eocene period the sea gradually regressed west and the area was covered with a veneer of alluvium.

f) Continental sedimentation and gradual uplift of the land continued throughout the Quaternary period. Development of present topography was finally accomplished.

Acknowledgements: Shris B. B. Jadeja, D. Joshi, J. P. Kansara and Malkani assisted during the field work. Their contribution is gratefully acknowledged.

References


