CHAPTER 7

HEAVY MINERALS

The heavy minerals are studied to trace the area of source rock of the sediment and reconstruction of paleo-geographic and climatic conditions. Range tables are utilized for the correlation purposes of the lithostratigraphic units (Evans, Hayman and Majeed 1934, pp.27-47). To measure the maturity of the sandstone both in stratigraphical and regional areas Z.T.R. maturity index are utilized (Hubert 1962 pp.443-444). Dispersal is studied with the help of visual roundness and sphericity of zircon, rutile and tourmaline (Power 1953, p.118, Krumbein 1934, pp.65-77).

Frequency diagrams of length, breadth and elongation ratios are used for the differentiation and correlation of the lithostratigraphic units and as measures of attrition. Likewise, the catena diagrams are also utilized (Smithson 1939, pp.297-309, 348-361, 417-427; Poldervaart 1955, pp.433-461; Venkatarathnam and Rao 1968, pp.20-29).

7.1. MINERALOGY :

The sandstones of the Mahadek Formation of Dawki area yield the following heavy mineral assemblage - opaque minerals (Magnetite, ilmanite and hematite etc.), garnet, rutile, zircon, epidote, chloritoid and tourmaline. The heavy
mineral corps of the sandstone range from 0.022 to 0.037 percent by weight.

**Opaque Minerals:**

The opaque heavy minerals are most abundantly present in the sandstones of Mahadek Formation. The volumetric distributions of opaque heavy minerals vary from 28.30% to 94.83%. There is no marked change in the frequency distribution of opaque minerals in the stratigraphic succession throughout the area.

**Garnet:**

Garnet is differentiated into two types, namely pink variety and colourless variety. The colourless variety predominates over the pink variety. High relief and poor cleavage marked by sub-concoidal fracture, is the characteristic of garnet. There is marked change in the frequency distribution of garnet in the stratigraphic sequence throughout the area. It ranges from 0.00% to 70.44%. Most of the grains are found in irregular forms. Some are moderately rounded (Plate 16A).

**Rutile:**

Rutile grains are mostly reddish brown and fowy-rad in colour. Distribution of prismatic and subhedral grains of rutile in the sandstones of Dawki area are found to vary from
0.00% to 3.60%. Foxy red variety predominates over the reddish brown one (Plate 16B).

**ZIRCON:**

Zircon is another important persistent heavy mineral of the Mahadek Formation. Varieties of colours are generally displayed by zircons. Idiomorphic grains are generally pale-grey in colour with very little evidence of abrasion. Colourless to cloudy variety often shows a well-developed zoning and houses foreign minerals as inclusions. The euhedral zircon with sharp pyramids gives light straw yellow colour and frequently contains inclusions of needle-like colourless irregular zircon. Fragmental zircon includes angular and sub-angular grains with or without vacules. Usually such grains are light grey with tinge of orange yellow. More rounded varieties are light pink in colour. This variety seems to be second cycle zircon. Volumetric distribution of zircon is found to be from 0.62% to 60.15% (Plate 15B).

**EPIDOTE:**

Epidote is either absent or ranges up to 1.62%. Epidote is pale yellowish green in colour and shows slight pleochroism. Irregular and rather angular grains are common. A further diagnostic feature is the brilliant green purple red interference tint observed in most clear individuals.
(Plate 16B). It is pleochroic -

\[ x = \text{colourless} \]
\[ y = \text{pale greenish yellow} \]
\[ z = \text{pistachio green (}Z > Y > X\text{)} \].

**CHLORITOID:**

Chloritoid commonly occurs as scaly flakes, often consisting of several flakes, partly superposed. Cleavage is almost perfect. The mineral is faintly persistent throughout and shows the distribution from 0.17\% to 2.57\%. It is represented by blue flakes with green and indigo blue in colour. Chloritoid displays the following pleochroism -

\[ x = \text{light brown} \]
\[ y = \text{light blue} \]
\[ z = \text{yellowish green (}Z > X > Y\text{)} \]

**TOURMALINE:**

In the heavy mineral residue tourmaline shows variation from 0.00\% to 13.75\% (Plate 16C). Tourmaline occurs mostly as subhedral to euhedral grains with brownish, colourless and blue in colour. It also gives some rounded and irregularly fractured grains (Plate 16C).

On the basis of colour and inclusion, tourmaline grains are grouped into four types:

(1) Brown tourmaline are strongly dichroic as
\[ X = \text{straw yellow} \]
\[ Z = \text{dark brown (} Z \succ X \text{).} \]

Mostly these are prismatic grains having the inclusion of bubbles, air cavities etc. which elucidates its derivation from granitic rocks (Krynine 1946, p.68).

(2) The other type of tourmaline with diversified habits like - rounded, euhedral and sub-hedral shows diachroism as,

\[ X = \text{pale pink} \]
\[ Z = \text{deep pink (} Z \succ X \text{).} \]

This variety of tourmaline possesses inclusions of opaque particles. Pink tourmalines are also derived from acid igneous rocks (Feo-Codecido, 1956, p.994).

(3) Another type of tourmaline gives diachroism as,

\[ X = \text{gray} \]
\[ X = \text{light lamen yellow (} Z \succ X \text{).} \]

This type also contains vacuoles, inclusions of opaque particles and is generally rounded.

(4) Blue tourmaline bears cavities and is dichroic with

\[ X = \text{mauve} \]
\[ Z = \text{blue (} Z \succ X \text{).} \]

This type of tourmaline points its derivation from pegmatites (Krynine 1948, p.68; and Feo-Codecido, 1956, p.994).
The volumetric distribution of minerals like zircon and tourmaline as well as iron minerals are more or less uniform, but the distribution of garnet is not so. It is concentrating in the lower members particularly, the arkosic member. The distribution of heavy minerals in the proposed area is arranged according to their abundance as follows: zircon, tourmaline, garnet, epidote, rutile and chloritoid.

Most of the heavy minerals show their size variation from sub-angular to rounded as well as well rounded. The heterogeneity of the size of the heavy minerals indicates multiple source rocks at different distances. The rounded as well as subrounded grains indicate long transport i.e. longer dispersal, and angular and subangular grains indicate short transport i.e. near provenance.

Presence of zoned zircon in the sediments of the area indicates the source rock to be igneous. There is no proper sign of metamorphic derivation except the presence of garnet.

7.2. **FREQUENCY DISTRIBUTION**:

In the sandstones of the Mahadek Formation the predominant heavy mineral is the opaque minerals i.e. hematite, magnetite, ilmanite and limonite. Persistant volumetric prominence of the opaque minerals in all the
sections of the area is a characteristic feature. The frequency of garnet is exceptionally higher in the lower member of the Dawki-Sokha section (Fig. 23B). In all the sections it gradually reduces in percentage in buff coloured Echinoid bearing sandstone member and comparatively increases in the steel gray coloured Nautilus bearing sandstone member and at the top i.e. in hard and fine gray coloured sandstone member it again decreases. Frequency of zircon is comparatively higher in the lower member of sections located at Dawki-Pamshutia, Sokha-Nongtalang and Dawki-Muktapur (Fig. 23 A, C, D), but it is noticeably lower in the lower member of Dawki-Sokha section. It is maximum in the buff coloured Echinoid bearing sandstone member and the next medium to fine grained sandstone member in all the sections. At the top of the members it gradually decreases except the Dawki-Sokha section. In the Dawki-Sokha, and Sokha-Nongtalang sections the frequency of tourmaline is comparatively lower in the bottommost member in comparison to the immediate overlying member. In Dawki-Pamshutia section on the other hand, the topmost and the bottom most members show comparatively lower frequency of tourmaline than the middle members. Dawki-Muktapur section, on the contrary shows a reverse frequency of the Dawki-Pamshutia section. Chloritoid is almost homogeneous except in the middle of the members in all the sections. Epidote on the other hand shows compara-
comparatively higher frequency with the stratigraphically higher members of the sections. Frequency of rutile is comparatively higher in the lower members of the section of Dawki-Pamshutia, Sokha-Nongtalang and Dawki-Muktapur. In Dawki-Sokha section, the frequency is proportionately higher in the middle members.

7.3. Z.T.R. MATURITY INDEX:

The maturity index of the heavy minerals like zircon, tourmaline and rutile in the sediments of the Mahadek Formation which is a measure of the maturity of the sandstone is found to vary the index value from 43.75 to 99.48. The maturity index of the sediments of the formation as expressed by the Z.T.R. maturity index is medium to good. The value of the maturity index distinctly decreases in the arkosic sandstone member in sections of Dawki-Sokha and Sokha-Nongtalang. It is comparatively higher in Dawki-Muktapur and Dawki-Pamshutia sections. The Echinoid bearing buff coloured sandstone member shows higher value of maturity index in almost all the sections. The value of maturity index distinctly decreases in the steel gray coloured Nautilus bearing sandstone member in all the sections. The value of maturity index comparatively increases in the immediate overlying medium to fine grained sandstone member and then decreases in the topmost sandstone member in all the sections (Fig. 23).
7.4. ROUNDNESS AND SPHERICITY:

The visual determination of the roundness of zircon, tourmaline and rutile grains varies from 0.26 to 0.54, from 0.31 to 0.48 and from 0.35 to 0.47 respectively. The sphericity of the minerals vary from 0.073 to 0.283. However, roundness and sphericity fail to exhibit any conspicuous zone of concentration from bottom to top of the formation.

7.5. LENGTH, BREADTH AND ELONGATION RATIO OF ZIRCON AND TOURMALINE:

The maxima in the elongation frequency curves occur at 1.10, 1.20, 1.40 and 2.00 mm. (Fig. 24A) in the lowermost member i.e. arkosic sandstone member (Fig. 15) in all the sections. Maxima in the elongation frequency curves occur at 1.40, 1.70, 2.00 and 2.50 mm. in the buff coloured Echinoid bearing sandstone member of Sokha-Morshol-lang section (Fig. 15) but maxima at 2.50 mm. is missing in other sections (Fig. 24B). In the gray coloured Nautilus bearing sandstone member of Dawki-Sokha section, (Fig. 15) the maxima occurs at 1.20, 1.50, 1.70, 2.00 and 2.40 mm. (Fig. 24C) but in other sections it occurs besides these at 1.40 mm. In the topmost member e.g. medium to fine grained sandstone, the maxima occur at 1.50, 1.70, 2.00 and 2.50 mm. respectively in all the sections (Fig. 24D).
The maxima in the length frequency curves occur in the arkosic sandstone member at 0.13, 0.19 and 0.23 mm. (Fig. 25A) in Dawki-Sokha section; but in the Sokha-Nongtalang section it occurs at 0.17 and 0.23 mm. The maxima in the buff coloured Echinoid bearing sandstone member occur at 0.13 mm. (Fig. 25B) in all the sections except in the Dawki-Pamshutia section where it occurs at 0.10 and 0.16 mm. The maxima in the steel gray coloured Nautilus bearing sandstone member occur at 0.13 and 0.17 mm. in the Sokha-Nongtalang and Dawki-Muktapur sections and 0.13 and 0.19 mm. in other sections (Fig. 25C). The topmost medium to fine grained sandstone member shows the maxima at 0.16 mm. in the Dawki-Pamshutia and Sokha-Nongtalang sections, 0.13 and 0.19 mm. in the Dawki-Muktapur section and 0.13 mm. in Dawki-Sokha section (Fig. 25D).

The maxima in the breadth frequency curves occur in the arkosic sandstone member at 0.07 and 0.13 mm. (Fig. 25B) in Dawki-Sokha section and at 0.13 and 0.19 mm. in Sokha-Nongtalang section. In the buff coloured Echinoid bearing sandstone member the maxima occur at 0.07 mm. only in all the sections (Fig. 25B). The maxima in the steel gray coloured Nautilus bearing sandstone member occur at 0.07, 0.13 and 0.19 mm. (Fig. 25C) in Dawki-Sokha section and at 0.07 mm. in other sections. In the uppermost member maxima occur only at 0.07 mm. in almost all the sections (Fig. 25D).
7.6. CATENAE OF ZIRCON AND TOURMALINE:

Smithson's diagram expressing the relationship between length and breadth shows that the catenae of zircon touch the 1:1 line and cross the 1:2 line but fail to touch the 1:5 line. Majority of the points are within the limit of 1:1 and 1:2 lines (Fig. 26A, B, C, D etc.). Catenae of tourmaline also touch the 1:2 line (Fig. 27B, D, E). The base of the catenae of both zircon and tourmaline rests on the 1:1 line. The position of the catenae in all the cases, further shows that the scattering is appreciably away from the origin of the co-ordinates implying less attrition during transportation. Further, the wing shaped catenae implies that the sediments are water laid.

7.7. SUMMARY:

The heavy minerals are represented by opaque minerals, garnet, rutile, zircon, epidote, chloritoid and tourmaline. The opaque minerals predominate over other minerals. Garnet and rutile occur comparatively in higher proportion in lower members of the formation. Though zircon and epidote show fluctuations in distribution, chloritoid is more or less uniform. The sandstones are characterised by the medium to good Z.T.R. maturity index.