A PETROLOGIC DIMENSIONAL FABRIC AND STATISTICAL STUDY OF PURBATOLI INLAND PLACERS, DISTRICT RANCHI, BIHAR*

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The results of the analysis of texture and composition place these placers in the group of arkosic sands. The quartz, rock fragments and the different varieties of heavy minerals indicate possibly a granitic terrain as the source area. Study of the characteristics of different minerals indicates absence of any diagenetic effects, a perfect preservation, short transport and a young age (?) for the placers. The mean direction of the sedimentary transport shown by the preferred grain orientation indicates a local ENE-WSW slope. Based on the size analysis and the statistical studies, the fluviatile conditions of deposition are proved. The placers are classified in the group of 'stream or valley placers'.

INTRODUCTION

Presence of anomalous radioactivity in the thin mantle of sands distributed over parts of Ranchi and Purulia districts of Bihar and West Bengal respectively has already been reported (Shirke and Chatterjee 1958). Subsequently several workers of the Department of Atomic Energy, Atomic Minerals Division, have carried out systematic investigations in different parts to evaluate the potentialities and nature of this inland placer.

The present paper deals mainly with the results of augerhole sampling carried out in the Ranchi district of Bihar (Toposheet No. 73E/3), in parts of these inland placers around Hururi (23° 26′ : 85° 13′), Purbatoli (23° 28′ : 85° 12′) and Patratoli (23° 26′ : 85° 12′), about 10 miles NNW of Ranchi town. The area was divided into three blocks of 4 square miles each, and each block was gridded for the collection of augerhole samples at a grid interval of 660′ × 660′, and one composite sample for each block was collected. An isopach/isorad map of the area was prepared (Fig. 1). A comparative study of the placer sands and granitic country rocks was carried out, and an effort has been made to bring to light the provenance, dispersal and depositional environments of these placers.

GEOLOGICAL SETTING

The terrain investigated is dominated by highly weathered porphyritic granites presumably of Chota Nagpur gneiss. The foliation of the country

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rocks is around NW-SE, and the dip of the same which ranges from 45° to 50° is directed towards SW. Occasionally satellitic bands of pegmatites are found in these granites.

The granite is light coloured, medium-grained with porphyroblasts of feldspars. Generally speaking, the rock is made up of quartz, feldspars, muscovite with zircon, rutile, epidote, sphene, monazite, ilmenite, magnetite, apatite, etc., as accessories. A petrological study of these granitic rocks has revealed that monazite is totally absent from some of the samples while in others it is present. The total percentage of heavies in the granite samples analysed varies between 2 and 8·5 per cent.

Petrography

The indication of movement of sediments and its provenance can most easily be determined by assuming that certain constituents remained unaltered throughout the history of sediments. In petrographic studies minerals zircon, tourmaline, quartz, etc., have generally been accepted as resistant to a greater or less extent and these have, therefore, been used as reference and index minerals in studies on the genesis of Purbatoli inland placers.

(*a*) *Gross Lithology*

Lithologically the placer sands show marked variations from its base to the top (Fig. 2). They are in apparent confirmity with the underlying granitic rocks and appear to present a gradational contact. Mostly the sands rest over a thin band of angulated fragments of vein quartz.

Some of the sections exposed near Purbatoli and Hururi are typical and can be taken as the representative of the other sections in the area investigated. In these places the lower zone of the placer sands resting over angulated fragments of vein quartz is 1 to 2 feet in thickness, and is represented by partly weathered parent rock. This lowermost zone is followed up by an intermediate zone of plastic to semi-plastic nature, which is generally 1 to 2 feet in thickness. Finally, both these zones are overlain by a thick upper zone 4 to 5 feet in thickness. Locally, some black partings or concretions which are either ferruginous or carbonaceous are also found. Usually the top of the placer sands is covered with a 6 inch to 2 feet thick mantle of lateritic soil.

At some restricted places, viz. ESE of Purbatoli and Hururi, some bedding-like structures are exposed.

(*b*) *Composition and Texture*

The results of the analyses of mineral composition (Table 1) clearly indicate that the Purbatoli placer sands belong to the arkosic type. The dominant detrital components are quartz, feldspars, micas, varieties of heavy

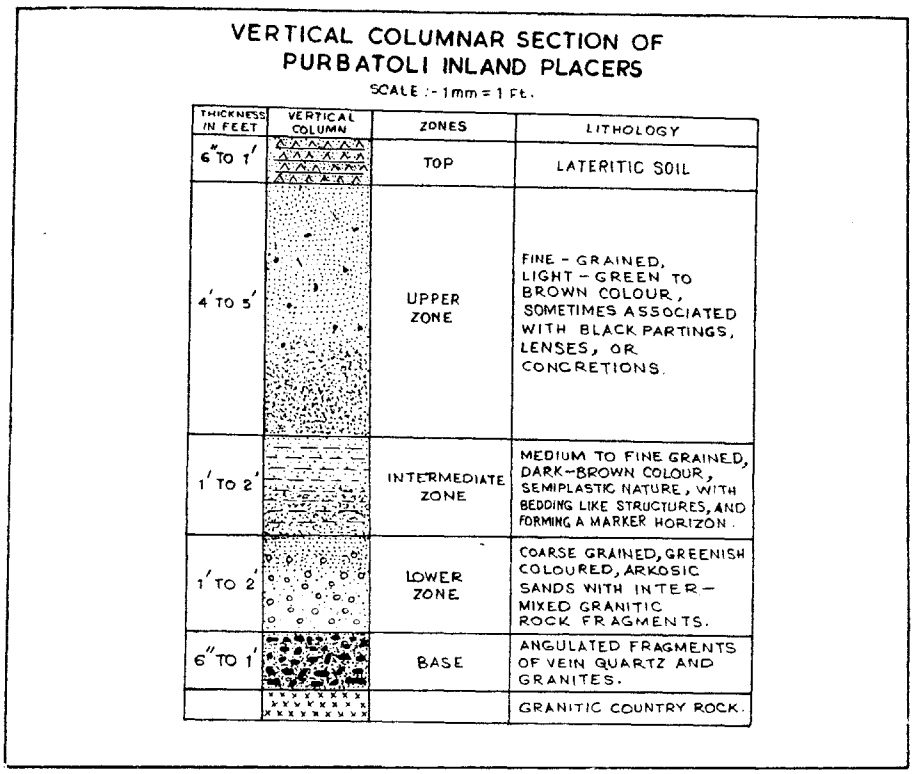

FIG. 2.

minerals including zircon, tourmaline, monazite, ilmenite, magnetite, rutile, epidote, sphene, sillimanite, apatite and fine-grained matrix of silt and clay. Rock fragments and iron oxides are the minor constituents. Texturally these placer sands are from coarse- to fine-grained. The sorting value calculated after Folk and Ward (1957) ranges between 1·35 and 1·54 indicating poor sorting.

TABLE 1

Modal composition of Purbatoli inland placers

Name of minerals		Percentage by volume
Quartz		56·3
Feldspars	Microcline	19·9
	Plagioclase	5·8
Micas		2·6
Accessories (heavy minerals, etc.)		0·9
Matrix	Clay	10·8
	Iron oxides, etc.	3·6

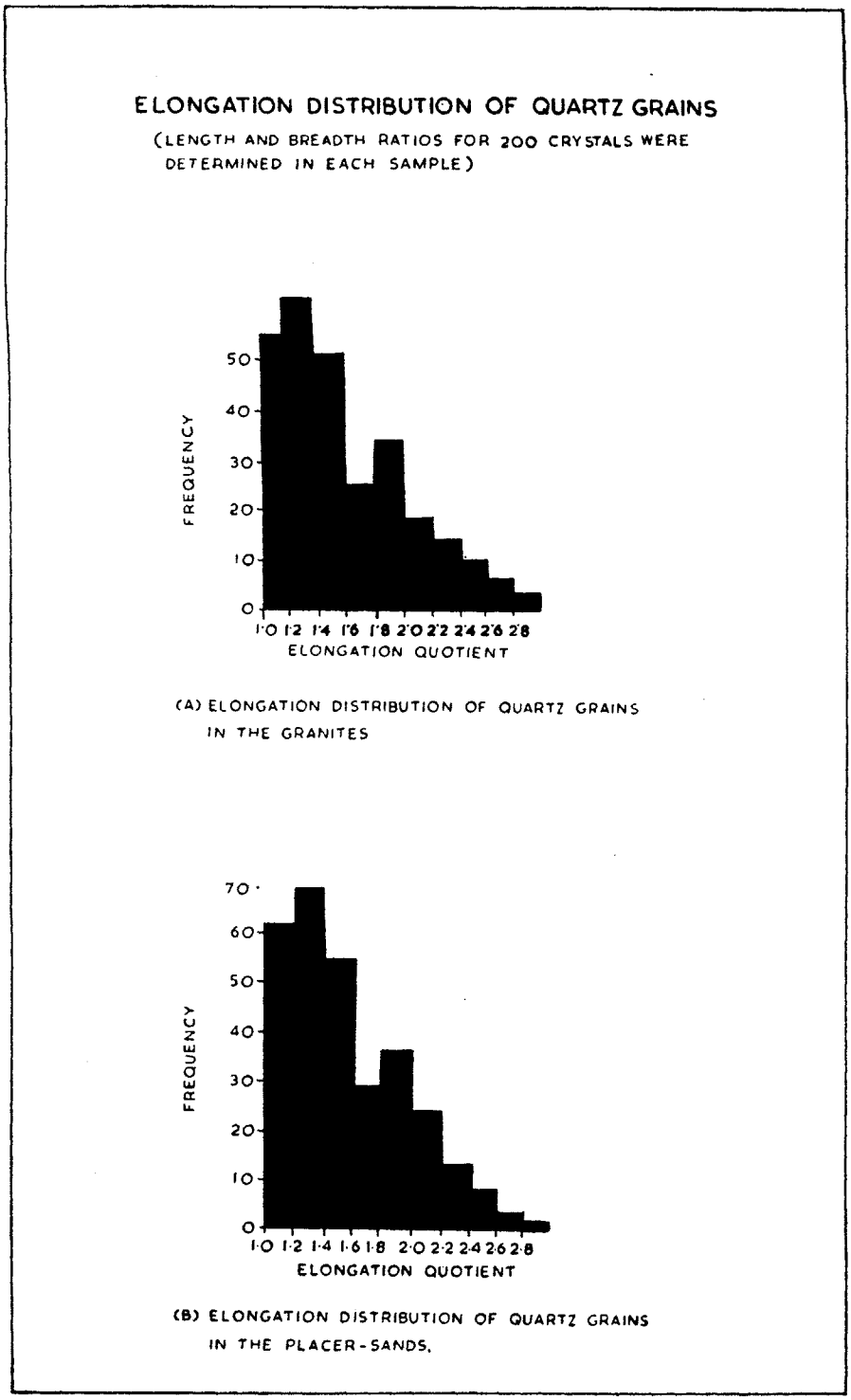
ELONGATION DISTRIBUTION OF QUARTZ GRAINS
(LENGTH AND BREADTH RATIOS FOR 200 CRYSTALS WERE DETERMINED IN EACH SAMPLE)
FREQUENCY
50
40
30
20
10
0
1·0 1·2 1·4 1·6 1·8 2·0 2·2 2·4 2·6 2·8
ELONGATION QUOTIENT
(A) ELONGATION DISTRIBUTION OF QUARTZ GRAINS IN THE GRANITES
FREQUENCY
70
60
50
40
30
20
10
0
1·0 1·2 1·4 1·6 1·8 2·0 2·2 2·4 2·6 2·8
ELONGATION QUOTIENT
(B) ELONGATION DISTRIBUTION OF QUARTZ GRAINS IN THE PLACER-SANDS.

FIG. 3.

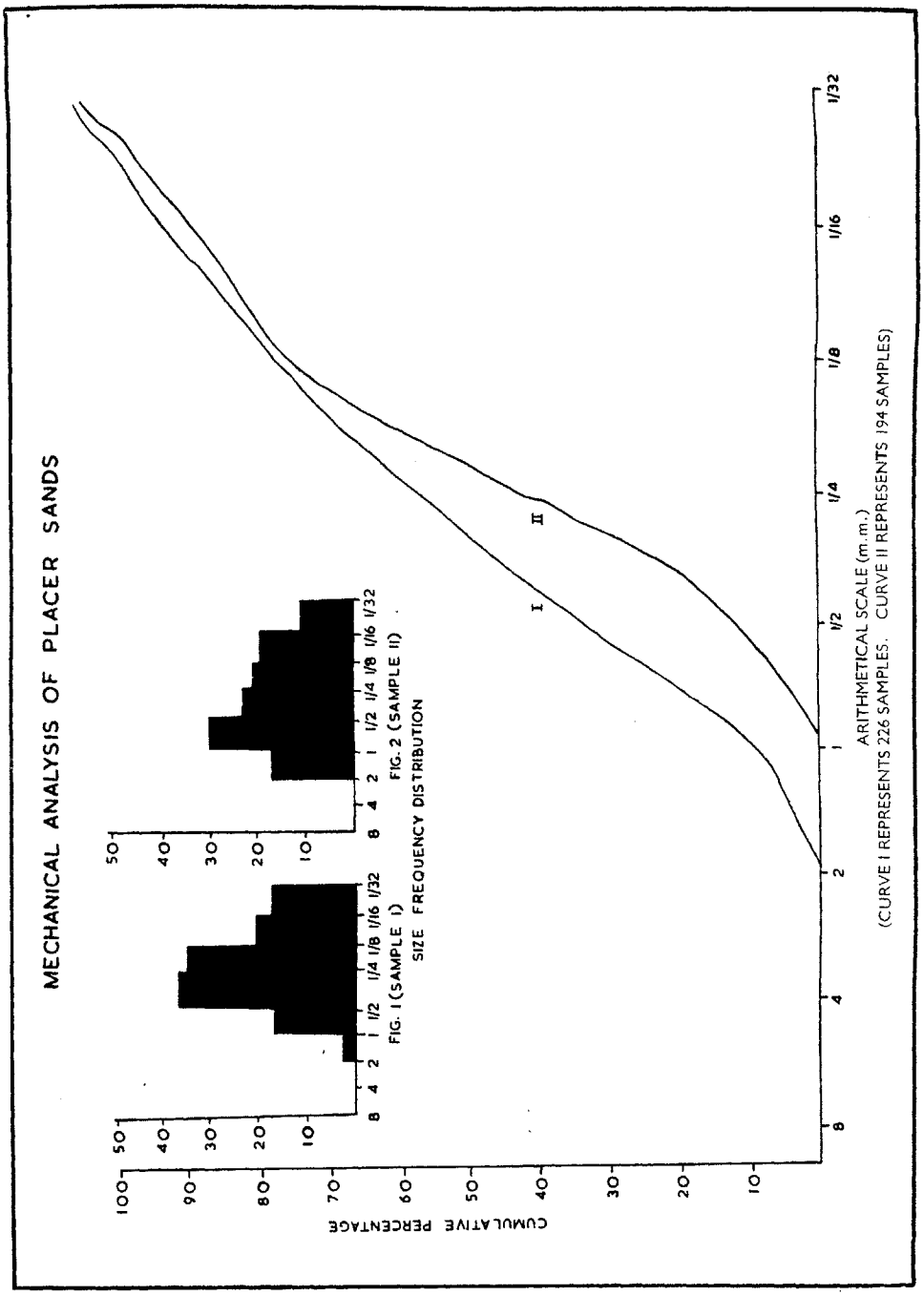

FIG. 4.

(c) *Detrital Particles*

QUARTZ—Detrital quartz is one of the principal constituents of these placer sands. To find the nature of these placers, quartz proved to be an important

and convenient index mineral being widely distributed in these sands and the surrounding country rocks. The identification of the igneous quartz variety is based upon such criteria as elongation ratio determined after Bokman (1952). About 70 per cent of the elongation of the quartz grains lie in the class

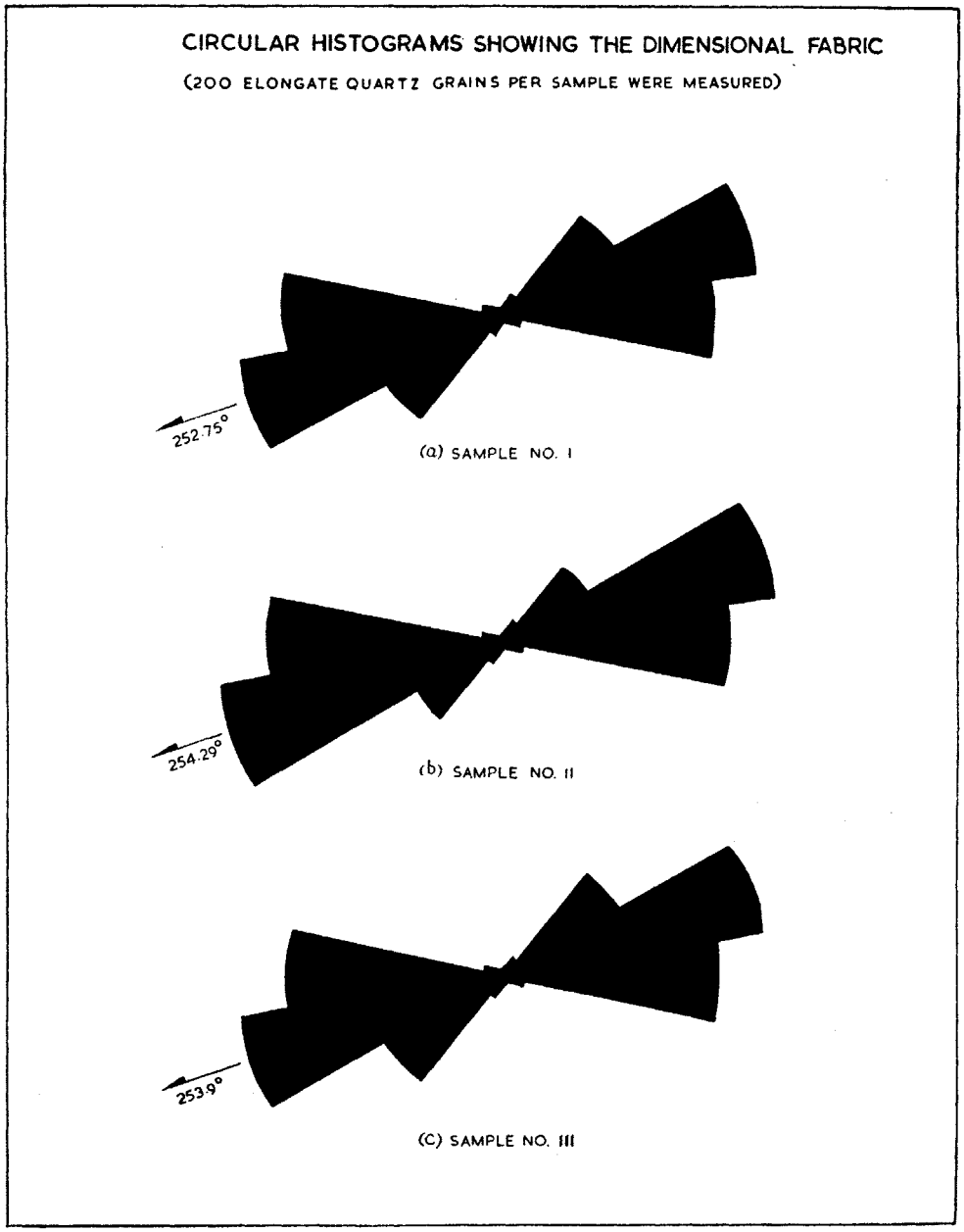

FIG. 5.

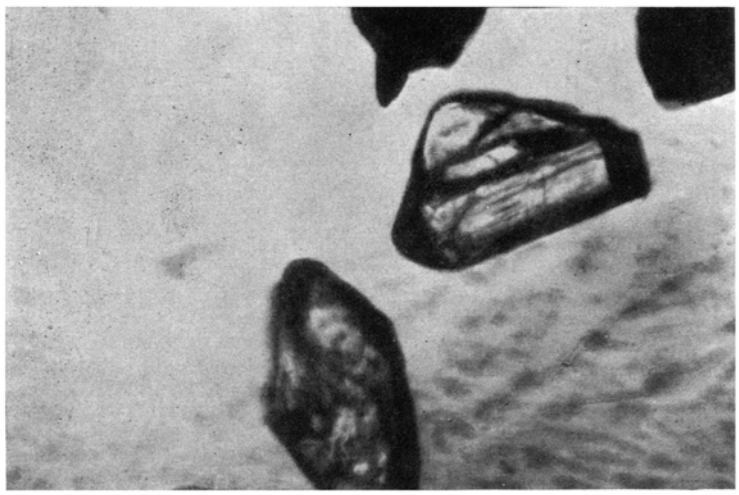

FIG. i. Zircon crystals from placer sands (Block I). Note the outgrowth in zircon crystals (120 mesh size). ×150.

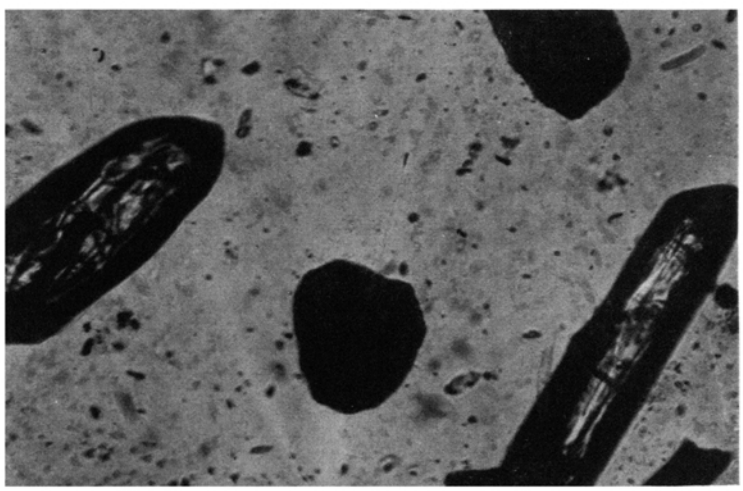

FIG. ii. Zircon crystals from placer sands (Block II) showing zoning and inclusions (120 mesh size). ×150.

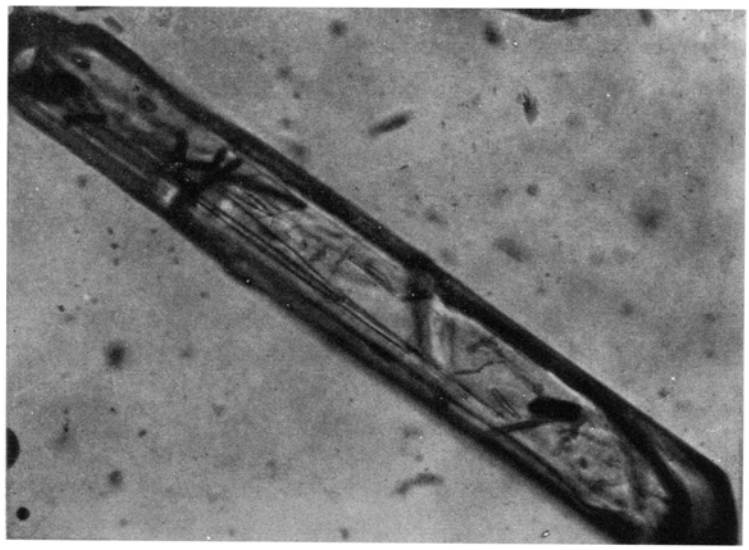

FIG. i. Zircon euhedral crystals from placer sands (Block III) showing zoning and inclusions (200 mesh size). ×170.

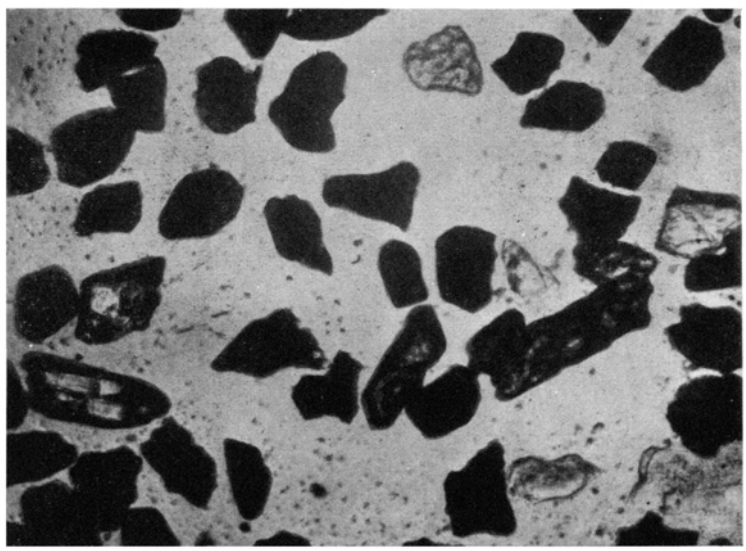

FIG. ii. Monazite, zircon and opaque association from placer sands (Block III) (−200 mesh size). ×170.

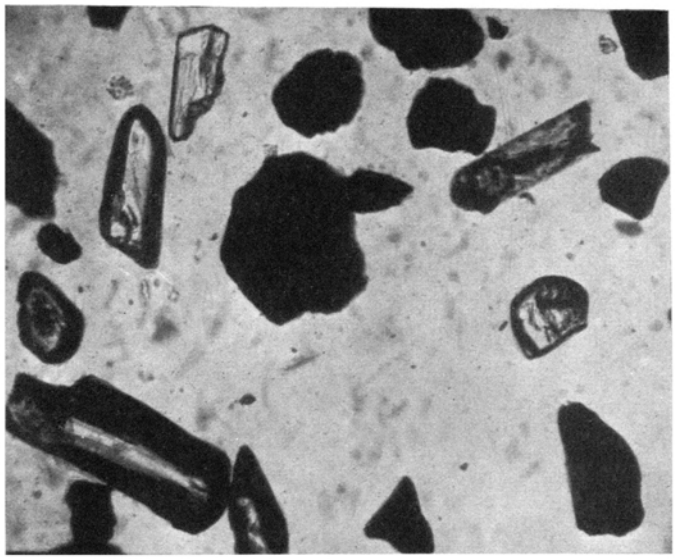

FIG. i. Monazite, zircon and opaque association from the placer sands (Block III). Note euhedrism and zoning in zircons (−200 mesh size). ×170.

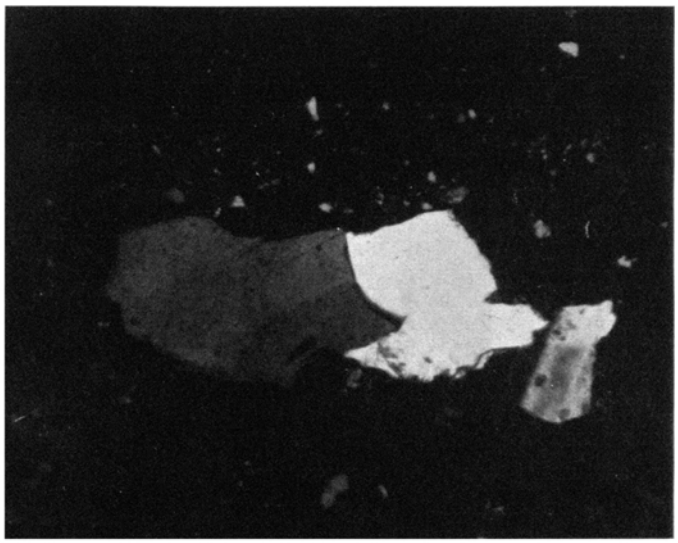

FIG. ii. Quartz crystals from placer sands (Block II) showing a wavy extinction. ×250.

of 1·2–1·4 which clearly indicate derivation of these quartz grains from the granites (Fig. 3). This is further supported by the similarity in the wavy extinction measured both in quartz grains from the granites as well as those from the placer sands.

FELDSPARS—The feldspars are comparatively more rounded than the quartz and are slightly altered, which indicate absence of any solution effects, less transport and young age (?).

MICAS—Clastic micas are generally fine-grained and subrounded. The micas are represented by both biotite and muscovite.

MATRIX—The matrix materials in the placers consist of clay and ferric oxide. It is difficult to identify the types of clay minerals present in the matrix using ordinary petrographic techniques. Fine, scaly and lath-shaped 'white mica' or sericite is commonly present and forms a major part of the matrix. Ferric oxide commonly forms coating on detrital grains and occurs as finely distributed black particles.

HEAVY MINERALS—The heavy minerals are subdivided into two groups of minerals, viz. opaques and non-opaques.

(i) *Opaques*—They are angular to subangular and form an important constituent of heavy minerals. The following types are identified (Plate IV, fig. ii; Plate V, fig. i):

Magnetite—The grains are generally unaltered and grey in colour.

Ilmenite—The grains of ilmenite show purple grey colours in reflected light. Occasionally the mineral grains alter to leucoxene.

(ii) *Non-opaques*—The following non-opaque minerals among the heavies are identified:

Zircon—The zircons could be divided into the following categories on the basis of their colour variations:

(1) White or colourless, (2) grey to bluish grey, (3) mauve, (4) pink to red, (5) pale yellowish green.

Several characters of zircon including colour, zoning, inclusions and grain shapes show that the zircon in the placer sands is similar to that in the granites. Both the colourless and coloured varieties are present. They are generally perfectly euhedral and only at places the pyramidal of zircon are torn out indicating short distance of transport (Plates III–V). According to Carroll (1957) the junction of the pyramidal faces with prismatic faces are generally considered as weak zones for weathering. Occasionally the grains show a dusky appearance due to crowding of inclusions, and the grain may be called Malacone variety (Plate III, fig. ii; Plate IV, fig. i; Plate V, fig. i). This variety may generally be formed from the colourless variety and the hyacinth variety due to emanation of radioactive elements. The radioactive zircon has a major contribution to the radioactivity

of these placers. The measurements made on the elongation ratio of euhedral zircon of granites as well as placer sands remarkably show similarities in the quotient values.

Monazite—It shows subrounded, euhedral, pale yellow, deep brown and colourless grains (Plate IV, fig. ii; Plate V, fig. i). This mineral partly contributes to the radioactivity of these placers.

Tourmaline—Tourmaline grains are classified on the basis of their colour into the following types:

(1) Indigo to black, (2) pale blue to dark black, (3) pale yellow to dark brown, (4) pale brown to greenish brown, (5) pale greenish to dark.

The grains are subrounded, angular and prismatic. Inclusions of zircon, rutile and opaque minerals are occasionally noted. In terms of Krynine's classification (1948), it is of granitic origin.

Minor Non-opaque Heavy Minerals—This category includes rutile, epidote, sphene, sillimanite and apatite which together contribute an insignificant amount in the total detritus of heavy minerals.

Size and Dimensional Fabric Analyses

A detailed study was carried out in order to decipher the palaeocurrent directions of placer sands to locate precisely the provenance with textural character which reflects the environment of deposition.

Size Analysis—From grain size analysis made according to the formulae derived by Folk and Ward (1957), it is found that the median diameter ranges between 1·8 ϕ and 2·3 ϕ and the mean diameter varies between 1·9 ϕ and 2·5 ϕ. The phi-deviation values calculated clearly indicate these sands are of moderately to poorly sorted. The skewness and kurtosis values range between 0·09 and 0·1 and 0·84 and 1·03 respectively.

On the basis of Sahu's discriminative functions (1964), two composite samples from blocks I and II, each comprising of 226 and 194 auger samples respectively, were calculated to decipher the environments of depositions. $\bar{Y}u$ values less than $-7{\cdot}4190$ clearly indicate fluviatile origin for the placer sands.

Fabric or Grain Orientation Analysis

An apposition fabric analysis of the samples (Dapples and Rominger 1945) collected from these placer deposits was carried out to determine the dimensional fabric orientation of quartz grains in order to decipher palaeocurrent direction. Due to the paucity of other primary structures like cross-bedding, ripple marks, etc., the imbrication study of only the teardrop-shaped grains was carried out in the dimensional fabric analysis as suggested by Schwarzacher (1951).

Rose diagrams (Fig. 5) from the three blocks I, II and III show vector mean calculated after the vector summation method and the mode as shown in Table 2.

TABLE 2

Block No.	Resultant vector mean	Mode
I	252·75°	250°
II	254·29°	250°
III	253·9°	250°

From this study it is found that there was a consistent flow of sediments from ENE to WSW direction.

DISCUSSION

(*a*) *Provenance*

The detailed study of heavy mineral association affords the information that they are the first generation sediments, being essentially derived from an igneous terrain, and represent on the whole granitic debris.

A comparative mineralogical study of the placer sands and granitic country rocks depending upon the morphological characters and extinction angle of the quartz grains point out to the fact that the placer sands and granitic country rocks are compositionally, though not texturally, similar.

(*b*) *Dispersal*

The compositional similarity between the granites and placers indicates that the granitic source rock was subjected to incomplete weathering and the transportation was very short. But this is not the rule for the placers as a whole. Even at the present day, the granites in the area are being weathered and the material is likely to be transported by seasonal streams or rain water.

The limited available directional data in the small area covered points out strongly the evidence of the source area lying to the east-north-east. No doubt that the source area for this part of the placers was located towards east-north-east, but this statement cannot be generalized and it should not be construed to mean that the source of the placer sands for the whole region was located entirely in one area. Quite obvious in such a topographic basin, materials will be derived from geographically varied sources, and the direction of transport will show variations on a regional basis. However, it appears that one principal source to the east-north-east prevailed.

The rate of accumulation of these placers is directly proportional to the increase in depth of topographic basins, and thereby the thickness of the placers shows a tendency to increase towards valley regions. This is a clear indication of movement of the weathered material from the high to the low relief.

(*c*) *Depositional Environments*

Pettijohn (1949) believes that in an area suffering short transport subjected to incomplete weathering, any material of sand size may occur. Based on Krynine's mineralogical classification (1948*a*) of the clastic or detrital sediments, which correlates major tectonic or geomorphic cycle, Pettijohn (1949) believes that rapid erosion produces ill-sorted sediments that contain unstable minerals with poorly rounded edges. It is imperative from the freshness of the feldspar contents in placers that they are derived from the granites under the conditions of rapid erosion and rapid burial. The sand-sized micas present in the placers are moderately to well rounded. According to Krynine (1948*a*), this indicates a specialized set of sluggishly moving currents, with gentle to-and-fro motion. This is further evident by the presence of pebbly layers composed of quartz and undecomposed or fresh feldspar crystals of all sizes, and being engulfed in between the fine sandy material. Pettijohn (1949) accepting the views of Krynine says that arkoses are largely terrestrial accumulations. No doubt there are exceptions to these concepts but the finding of an exception does not invalidate the theory. This view is fully supported by the results of mechanical and statistical analyses of these ill-sorted immature arkosic sands, which prove them to be fluviatile in nature.

(*d*) *Geologic Significance, Nature, Origin and Age*

The geologic significance, nature, origin and age of Purbatoli inland placers are manifold. The main significant problem is the presence of undecomposed feldspars and other unstable minerals as in many arkosic sediments in the world. The abundance of fresh undecomposed feldspars in Purbatoli placer sands is characteristic of immature sands (Pettijohn 1949). He believes that 'high relief alone, and subsequent rapid erosion, will produce feldspathic sands even under humid climates'. This is further proved by the works of Barton (1916) and Krynine (1935) on some present-day arkosic sands formed under similar conditions. Pettijohn (1949) considered arkoses to be commonly associated with large-scale block faulting. Applying this view on a regional scale to this part of the country, we may find evidences of block faulting between Purulia and Ranchi plateaus, e.g. the sudden fall in the level of the two plateaus, followed by the straight granitic boundaries. But with limited information at hand, and that too after the work in a limited area, nothing can be easily

postulated on a regional basis and this view of Pettijohn cannot be supported here.

The other problem is related to the origin, nature and age of these placer sands. These inland placers show the absence of any 'pathologic features' and presence of chemical or mineral stability, with a perfect resistance to solution, decomposition and therefore the unstable minerals like feldspars, micas, apatite, etc., are preserved. And therefore these placer sands are not residual soil of chemical decay as the works of Pettijohn (1949), Reiche (1950), Krynine (1948*b*) and Trask (1950) have shown. The textural variations are prominent and an imbrication in quartz grains is highly developed. Therefore, the processes of weathering, transportation and deposition are very well recognized. Only the physical breakdown was the dominant resulting factor which caused a change from a massive to clastic state breaking solid rocks down to chemically unstable debris (Krynine 1948*b*). It is evident that this granite debris was further transported and deposited by stream and rain water.

According to Olson and Overstreat (1954), 'most of thorium minerals, on weathering and disintegrating of the enclosing rock, remain as detrital grains owing to insolubility and generally high specific gravity'. The weathered mantle thus becomes enriched in residual heavy minerals which gradually move down slope and down stream. According to Olson and Overstreat (1954), the Caroline Piedmont Placers show more heavy mineral concentrations near the streams, the placers becoming larger down stream but leaner because of admixture of monazite-free material from the other tributaries (Mertie 1953; Overstreat *et al.* 1956). The placer deposit on Horse Creek near Aiken, S. Carolina, was formed when the Cretaceous rocks rich in heavy minerals were eroded and they were reconcentrated in the fluviatile placer deposits. Like the Horse Creek placers, a significant variation in radioactivity is noted (Fig. 1). Firstly, the adjacent granite rocks are less radioactive than the placers; secondly, the part of placers located in the valley regions, depressions and nearby or along the stream courses show high activity as compared to the rest, showing therefore that the monazite, zircon and the other heavies have a tendency to have more accumulations in such regions, and thereby contributing high radioactive zones. This shows that the heavy mineral distribution is finally controlled by aqueous agencies like streams and rain water, with respect to the pre-existing terrain and the palaeoslopes. The action of any chemical agency resulting in the residual nature is therefore ruled out. These evidences point out in favour of considering these placers as belonging to the group of 'stream or valley placers' (Olson and Overstreat 1954).

It is commonly known that the maturity is a function of time and intensity of action which depend upon relief and climate respectively. If the

time is brief, the end product will be immature, regardless of the intensity (Pettijohn 1949). In the course of time, feldspar gets decomposed and the quartz/feldspar ratio becomes high. The immaturity of these sands, therefore, by and large postulates a young age (?). This is further supported by the presence of apatite, which is characteristically absent from the old soils (Pettijohn 1949). Compositionally the placer sands and the source rocks are similar. This shows that it has attained only the first stage of soil cycle, i.e. physical weathering effects. The old soils always represent a 'weathering complex' and a compositional similarity with the parent rock is impossible.

Conclusions

Purbatoli inland placers are essentially sands which are composed of quartz and feldspars, together with a little matrix which consists of iron oxides, mixed with fine silty or clayey material. The heavy minerals being grouped in the accessory minerals of the placer sands are the least abundant. Based on the mineral composition, the placer sands can be placed in the group of arkosic sediments, being essentially derived from a granitic terrain. They are unconsolidated, moderately to poorly sorted, pink or reddish coloured, immature, medium- to fine-grained sands, generally with obscure beddings, slump structures and lying as a 'blanket or sheet' over a granitic basement.

According to Pettijohn (1949), basically and fundamentally all the clastic sediments are the residues. Broadly speaking, Purbatoli placer sands are 'washed residues', where the parent rocks were disintegrated and subjected to a strong action of aqueous agencies, to get them fractioned into various size grades.

The results of petrographic, statistical and fabric analyses have helped to find out the provenance, dispersal and depositional environments of these inland placers. It is believed that a land of high relief with a mature topography existed towards east-north-east. The remnants of this high land form the present-day relief. Naturally, the rocks of this upland were of granitic type. The area was perhaps subjected to diastrophic movements, resulting in the weathering and erosion of the rocks forming the blocky material. From this east-north-eastern source area and other regions also, aqueous agencies carried freshly eroded material into the nearby topographic basins, depressions and valleys or the areas of low relief, and depositing it there. The distance of transport seems to be very short. These placers on the whole can be grouped as 'stream or valley placers'.

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