ON THE FLINTS AND CHERTS FROM THE UPPERMOST CRETACEOUS BEDS (THE NINIYUR STAGE) OF THE TRICHINOPOLY DISTRICT—S. INDIA.

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In his paper on the Cretaceous rocks of the Trichinopoly District[1] Blanford has stratigraphically classified them into three stages. Starting from the oldest, these are (*a*) the Utatur, (*b*) the Trichinopoly, and (*c*) the Ariyalur. He has further sub-divided the Ariyalur stage into the lower, the middle, and the upper, of which the rocks of the lower and upper sub-divisions are highly fossiliferous while the middle division is practically unfossiliferous. In describing the highly fossiliferous rocks of the upper Ariyalur division found near Sendurai, Niniyur, Yellakudumbur, etc., Blanford has drawn attention to the occurrence of two bands of flints and cherts associated with the limestones of this area. In a paper to be shortly published elsewhere, reasons have been given to show that the so-called upper Ariyalur beds of Blanford must be dissociated from the rest of the Ariyalurs and constituted into an independent stratigraphical unit called the Niniyur stage; and the two bands of flints and cherts mentioned by Blanford, whose study forms the subject of this paper, have been accordingly considered by us as belonging to this stage. One of these bands occurs about a mile south-east of the village of Sendurai and the other near Nattagooly, about 5 miles further north. As regards the nature of these flints and cherts, all that Blanford has said is that they resemble "in the mineral character and the nature of the enclosed organisms the chalk flints of Europe," and this obviously is not saying much. A detailed examination of this material is now made by us and the more important observations are embodied in this paper.

Nattagooly Area.

Loc.—About $1\frac{1}{2}$ miles north-east of the village of Nattagooly and due south of the village of Mathur. The band is 30–40 feet wide and is seen

[1] *Mem. Geo. Sur. Ind.*, **IV**, Part I.

for about half a furlong on the bed and sides of a small north and south nulla.

Mega.—The most striking feature of these flints is that they are highly shattered and readily break up into small splintery fragments. Even from their general appearance the flints of this area could be divided into two types —(i) the grey homogeneous chalcedonic type forming the main mass of the band with (ii) a dull, white, light, opal-like material at the top. Often in one and the same specimen we can see the gray chalcedonic material below gradually passing into the opal-like material above. On close examination both the types are seen to be fossiliferous—polyzoa, corals, and lamellibranchs being the common fossils. The corals are particularly abundant in the chalcedonic material where their calyces are very clearly seen, especially on weathered surfaces. The common form is *Stylina*. The lamellibranchs are commonly seen only in the opal-like material and are mostly in the form of impressions which are too fragmentary to be definitely identified ; but judging generally from their shape, size and ornamentation, these appear to be mostly of genera like *Cardita, Cardium, Corbis*, etc.

Micro.—When sections of these flints are examined under the microscope, we find that the two types described above show dissimilar appearance. Sections of the opal-like masses are seen to be composed mostly of opaque material except in places where we get the organic structures when we see distinct grains of quartz. In the case of the brown chalcedonic material, on the other hand, the entire section is made up of a homogeneous cryptocrystalline mass of silica, and in places where the organic structures are found, the grains become much bigger and are distinctly recognisable as quartz. Sections of both the types reveal a large number of foraminifers, chiefly of the family Miliolidæ—the common forms being *Biloculina, Triloculina*, and *Quinqueloculina*.

Sendurai Area.

Loc.—The flints of this area are well seen about a mile south-east of Sendurai especially along the cart track leading from Sendurai to Nallambal. This band is much longer than the one near Nattagooly and huge boulders of the flint are very commonly seen all over this locality. In some nulla sections we can see these flints overlying the unfossiliferous sandy clays of the middle Ariyalur division of Blanford.

Mega.—In general appearance these flints resemble the waxy brown chalcedonic type of the Nattagooly area. But these are more massive and often contain drusy cavities lined by tiny but beautiful crystals of quartz. Fragments of these flints are translucent at the edges and possess a

sub-conchoidal fracture. About ¾ mile south-east of Sendurai where we get the first *in situ* exposures of these flints, a striking feature is their "pebbly" character. The "pebbles" are as a rule well defined and rounded. They are usually white, while the general mass of the rock is reddish brown and thus the entire rock gets a characteristic mottled appearance. Proceeding further south-east, we find that the pebbly character gradually disappears and the rock becomes more and more homogeneous and compact. The upper portions of the band are highly weathered, giving rise to a porous type of flint in whose pores and cracks abundant earthy ferruginous material is found, due to infiltration from the Cuddalore sandstone. It may be pointed out here that though the general mass of the rock is all siliceous, a few of the flints and cherts still show internally traces of the original calcareous material which can be easily detected with a drop of acid.

Micro.—When examined under the microscope these flints are seen to be closely similar to the waxy brown chalcedonic variety described above from the Nattagooly area, *i.e.*, they are seen to be composed of uniformly homogeneous cryptocrystalline silica, except in places where we get the organic structures when we can recognise distinct grains of quartz. In several of the sections the drusy cavities appear and these are seen to be lined by concentric bands of radial-fibrous silica which under crossed nicols show exceedingly fine spherulitic and axiolitic structures. The central portion of the cavity, however, is filled up by a distinct mosaic of quartz grains. The "pebbly" nature of some of the flints noticed above is even more distinctly seen in sections than in hand specimens. Embedded in a matrix which is essentially similar to the general mass of the rock, we see a number of distinct and rounded pebbles, in the interstitial spaces of which we often see infillings of quartz in the form of mosaics, very fine grained in the margin and coarse in the middle. The chief organisms noticed under the microscope are corals and milioline foraminifers. The latter are similar to those in the Nattagooly flints but are not so abundant.

From the palæontological point of view the most remarkable feature of these flints and cherts from both the Sendurai and Nattagooly areas, is the presence of abundant algæ commonly noticed in all the sections. The white opal-like material of Nattagooly, for instance, is full of algal remains; most of the "pebbles" in the pebbly varieties noticed near Sendurai are nothing but rounded patches of algæ (Fig. 1), and the homogeneous massive varieties of the flints also show broad patches of algæ which often constitute the bulk of the rock (Fig. 2). The common form recognisable is *Archæo-lithothamnion*, but apart from this we can see that several other

types are present. We may here point out that these algæ are the first to be discovered from the Cretaceous rocks of India.[2]

We consider the abundant occurrence of algæ in these flints as of great importance, not only because it throws some light on the nature of the original rocks which have now been silicified into flints and cherts, but also because of the rich material which these sections provide for a detailed study of the South Indian Cretaceous algæ.[3]

From all that has been said above it will be obvious that all these flints and cherts are merely the products of silicification of original fossiliferous limestones, chiefly composed of algæ, corals, polyzoa, and milioline foraminifers, with a few lamellibranchs and gastropods. Of these the algæ are by far the most abundant and there is no doubt that they must have played a very important part in building up these limestones. The conclusion that these flints are merely silicified limestones is further supported by the fact that in both the Sendurai and Nattagooly areas, we see certain limestones alongside these flints ; and often it is possible to place side by side specimens of limestones and flints which are absolutely similar, both in hand specimens and in micro-sections—the only difference being that in one case the rock is calcareous and in the other, it is all replaced by silica.

In connection with the subject of this paper, we may also draw attention to two other localities in the Trichinopoly Cretaceous area where Blanford has mentioned the occurrence of flints and cherts ; *viz.*, (i) near Vilangudi about 9 miles south-south-east of Sendurai, and (ii) near Keelanottum about 6 miles south-east of Vilangudi. Like the flints and cherts of the Sendurai and Nattagooly areas, here also they overlie the unfossiliferous middle Ariyalur sands and clays ; but whereas the former have been described by him as part of the *upper* Ariyalurs those of Vilangudi and Keelanottum have been considered by him as belonging to the *middle* Ariyalur division, presumably because no fossiliferous limestones of the kind noticed alongside the flints near Sendurai and Nattagooly are found associated with the flints of these southern localities.

Of the two localities now under consideration, we find that it is only in the Vilangudi area that we get decent *in situ* exposures of these flints, while near Keelanottum we get only a few stray fragments with no *in situ*

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[2] L. Rama Rao : On the occurrence of *Lithothamnion* in the South Indian Cretaceous. *Nature*, **128**, 8th Aug. 1931, p. 225.

[3] These algæ from the flints and other associated rocks of the Niniyur stage are being described and identified in collaboration with Prof. Julius Pia of Vienna. A paper on this subject will soon be published elsewhere.

occurrence. We will therefore ignore this latter area for the present and proceed to give a brief account of the flints and cherts found near Vilangudi.

Vilangudi Area.

Loc.—Several outcrops of the flints are seen in the area about 1–2 miles south of the village. The most prominent of these is the one seen about 2 miles south-south-east of Vilangudi. Here the band is almost east-west and is more than a furlong in length, with a maximum width of about 25 yards. The rock occurs in huge boulders with a yellowish or reddish jaspery looking weathered exterior. A few small outcrops are also seen within half a mile north of the village. The flints of this area may at once be divided into two types: (i) the slate-gray homogeneous and compact variety, and (ii) the white or gray quartzitic type.

Type 1—

Macro.—This variety is common among the outcrops immediately to the north and south of the village. Rocks of this type are very homogeneous and compact, exactly like those of the Sendurai area; but whereas they are brown in colour, these are bluish gray. Here also we have a few pebbly varieties comparable to those of Sendurai. One or two echinoids and a few corals are the only recognisable fossils in hand specimens.

Micro.—Sections of this type are composed almost entirely of homogeneous cryptocrystalline or even amorphous silica. As in the case of the Sendurai area, the "pebbles" of the pebbly varieties are seen to be distinct algal patches.

Type 2—

The two big outcrops 1½ to 2 miles south of Vilangudi are chiefly of this type of rock. This has a ferruginous weathered exterior, but internally it is usually slate-gray in colour and distinctly granular; and a careful examination with a lens shows that the rock is more or less a quartzite. Some corals and a few fragmentary impressions of lamellibranchs and gastropods are the only fossils, and even these are well seen only on weathered surfaces. On the basis of their colour and texture, these can be divided into two varieties: (i) the fine grained gray quartzite, and (ii) the coarse grained saccharoidal quartzite.

Fine grained gray quartzite.—

Macro.—This type of rock is usually ash gray in colour, and though fine grained there is no room for hesitation in recognising the rock as a quartzite. In some places this rock type is seen to be traversed by numerous irregularly wavy threads of a dull, white, and highly porous material.

Small minute streaks of a similar character are also very abundant in the body of the rock. Sometimes these streaks form a regular mesh work, with portions of the rock enclosed within the meshes (Fig. A). Though at first sight the rock appears to be unfossiliferous a close examination with a lens shows the frequent occurrence of broad patches of corals in many of these specimens. The entire rock, however, is siliceous, there being little or no effervescence with dilute hydrochloric acid.

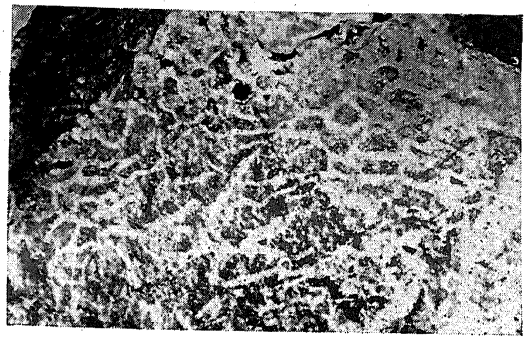

FIG. A.

Micro.—Sections of this rock-type are generally colourless and clear and under crossed nicols we see a regular mosaic of roughly equidimensional grains of quartz, a structure so typical of a quartzite (Fig. 4). The size of the grains, however, is variable being fine in some and coarse in others. In the latter case we sometimes see thin streaks of a more or less brown coloured material definitely occurring along the narrow interstitial spaces between the polygonal quartz grains, thus bringing into relief the outlines of the grains themselves (Fig. 3). The nature and disposition of this material seem to suggest the persistence of what in the original rock must have been the cementing material. In several of the sections we see a large number of irregularly oval or elongated patches which, where the section is sufficiently thin, show a definite organic structure easily recognisable as algal in character. Such algal patches are very common practically in all sections, although when the section is thick, it is difficult to recognise the algal structure in these patches which would then appear more or less structureless and opaque. Where the algal patch is fairly big and the structure more or less distinct, it is seen that under crossed nicols, the entire patch resolves itself into a regular mosaic of quartz grains as in the rest of the section, thus showing that it is a true case of a quartzite derived from the silicification of a fossiliferous rock.

In the macro-characters described above, attention was drawn to specimens where the rock is seen to be traversed by threads of a dull white material often forming a regular mesh work in the body of the rock. Sections of this type show under the microscope that this material occurring in threads is also algal in nature, the algal structure being clearly seen only in thin sections.

Apart from the algæ which are by far the most common, other organic structures frequently noticed are those of corals. In one of the slides we

get a very distinct transverse section of a compound coral which can be recognised as *Holocœnia*. Under crossed nicols the coral structure is also seen to be silicified and reveals a regular mosaic of quartz grains, thus sharing in the quartzitic character of the entire rock (Figs. 5 and 6). A similar effect is also seen in the case of a few milioline foraminiferal sections in some of the slides.

Coarse grained saccharoidal quartzite.—

Macro.—The quartzites of this type differ from the above in being more coarsely granular and often white and saccharoidal in appearance, thus including some examples of typical quartzites. In some places this rock is full of big sized corals mostly belonging to the genus *Heliastrea*, all completely silicified (Fig. B). In addition to the corals, some impressions of lamellibranch shells and casts of gastropods are also often found. Even in cases where the rock presents the appearance of a typical white saccharoidal quartzite, it is easy to see that the rock is almost entirely coralline in constitution.

FIG. B.

Micro.—Under the microscope sections of this rock-type show that they are largely composed of an opaque material with a few irregular colourless streaks and patches here and there. The opaque material is very much shattered and in places where the section is thin, shows a distinct algal structure. Under crossed nicols, the entire section resolves itself into a mosaic of quartz grains. A few sections of milioline foraminifers are also seen now and then, and these are all quartzitic now. Thus there is no doubt that this type is a true quartzite resulting from the silicification of a rock full of algæ.

From the above description it will be seen that the quartzites now under study are the result of silicification of an original fossiliferous rock containing a fairly large abundance of algæ, together with some corals, foraminifers, etc. ; and it also seems reasonable to suggest that the original rock must have been more or less of the nature of a fossiliferous sandstone. Beyond being almost entirely silicified and converted into a quartzite, the rock does not seem to have undergone any great degree of metamorphism, any changes in this direction being those of a kind confined to the earliest stages ; for as

Harker[4] says in speaking of the metamorphism of the arenaceous sediments, "the first definite landmark of advance is the recrystallisation of the clastic quartz. At first the shapes of the original grains are still discernible, if there is sufficient interstitial material to outline them."

A fossiliferous quartzite of this nature appears to be an unusually interesting type of rock. Dr. Lees in his paper on the chert beds of Palestine[5] has mentioned a similar rock-type which he describes as follows: "In some places an unusual quartzite bed outcrops interbedded with Cenomanian limestones. It is intensely white in colour and has a sugary surface texture. Mr. G. S. Blake showed me some definite, though indeterminate, fossil shapes in this quartzite which aroused suspicion as to its real nature. A thin section shows nothing but a regular mosaic of quartz crystals. Several opaque patches suggest some organic structure." Obviously Dr. Lees is here speaking of a rock very similar both in nature and origin to the saccharoidal quartzite that we are now describing; but whereas the fossil shapes he has seen are "indeterminate" and "suspicious", those in our type are absolutely clear and convincing.

A very interesting question that naturally arises at this stage is the exact stratigraphical relationship between these Vilangudi flints and quartzites and the flints and cherts of the Sendurai and Nattagooly areas which are definitely recognised as belonging to the Niniyur stage. The Vilangudi rocks are also the result of silicification of original fossiliferous rocks containing a large proportion of algæ together with some corals and milioline foraminifers, like those of the northern areas; and they also similarly overlie the unfossiliferous sands and clays of the middle Ariyalur division. From these facts one is led to conclude that these are stratigraphically equivalent to the flints and cherts of the Niniyur stage. If so we must postulate a southerly extension of the Niniyur rocks right up to at least 2 miles south of Vilangudi, if not as far south as Keelanottum. While such a conclusion appears justified on the basis of our present observations, we will reserve a definite statement on this matter till a thorough investigation is made of the country between Sendurai and Keelanottum. We will also then deal with the question as to when and how the silicification of these fossiliferous rocks took place to give rise to the present flints, cherts and fossiliferous quartzites.

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[4] A. Harker: *Metamorphism*. Methuen & Co., 1932, p. 241.
[5] *Proc. Geol. Assn.*, 39, Part IV, 1928, p. 445.

EXPLANATION OF PLATES.

PLATE I.

FIG. 1.—'Pebbly' flints—showing algal structure. ×40.

FIG. 2.—Broad algal patch. ×75.

PLATE II.

FIG. 3.—Fine grained gray quartzite showing the interstitial material between th quartz grains. ×60.

FIG. 4.— do. under ×nicols.

FIG. 5.—Fine grained gray quartzite showing coral structure. ×32.

FIG. 6.— do. under ×nicols.

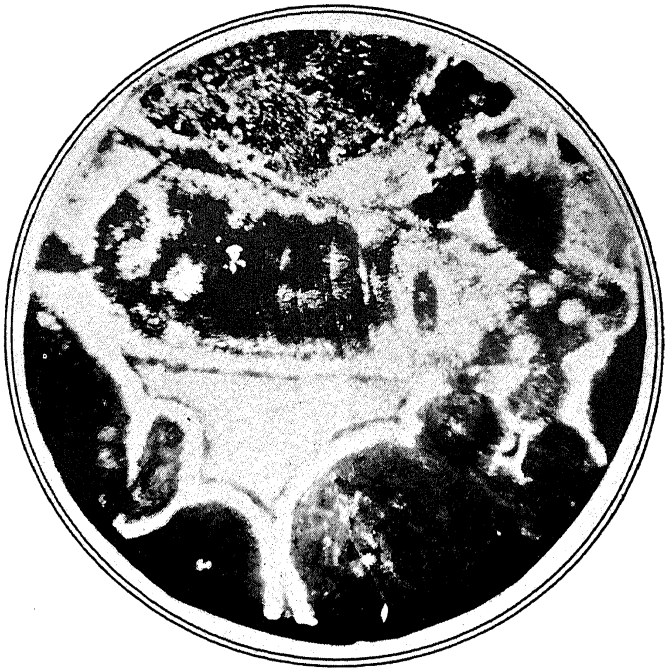

FIG. 1

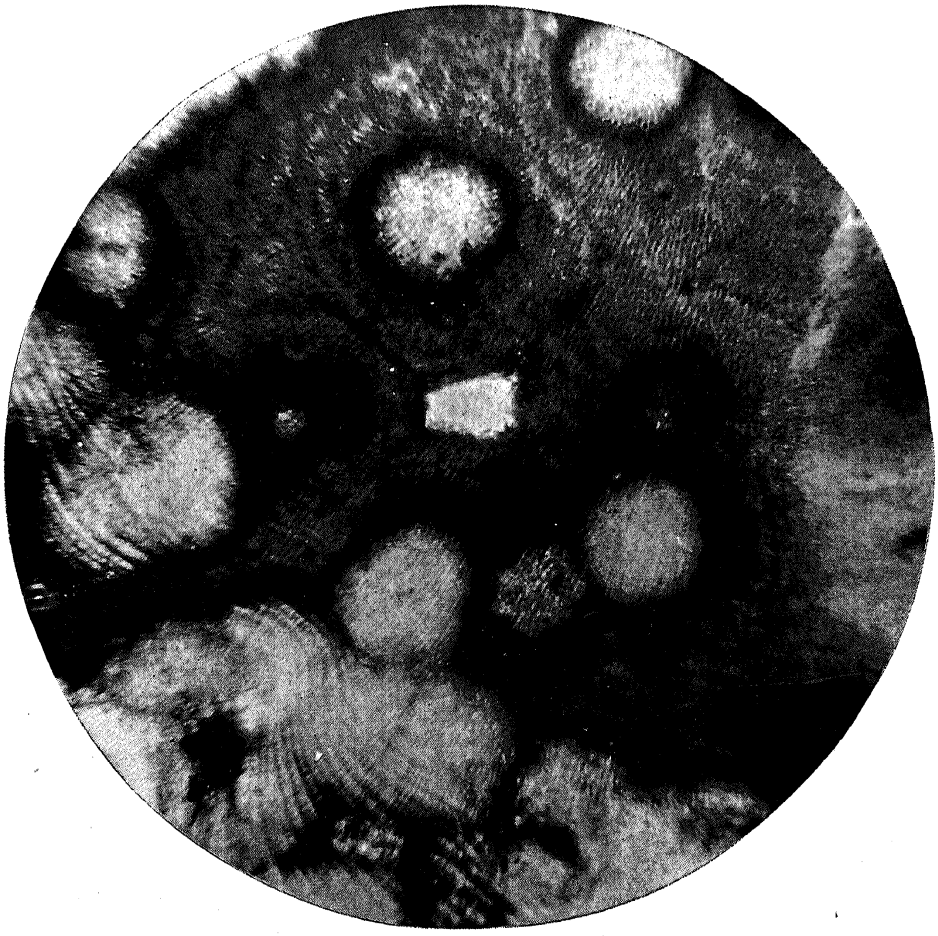

FIG. 2

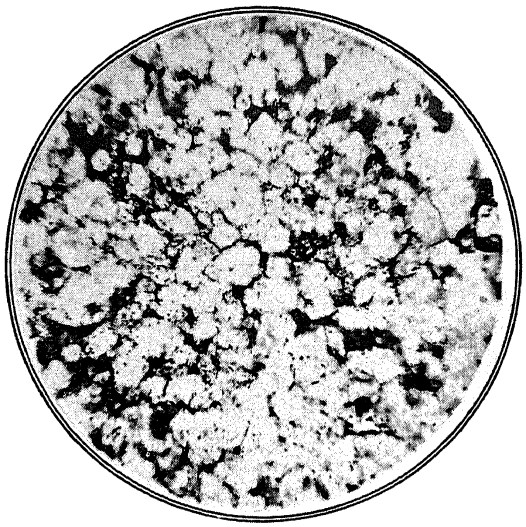

FIG. 3

FIG. 4

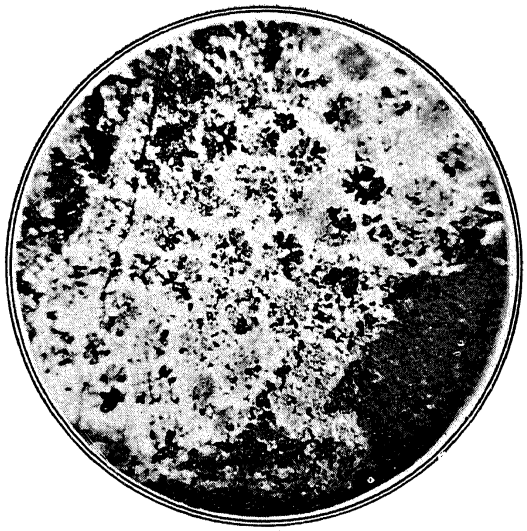

FIG. 5

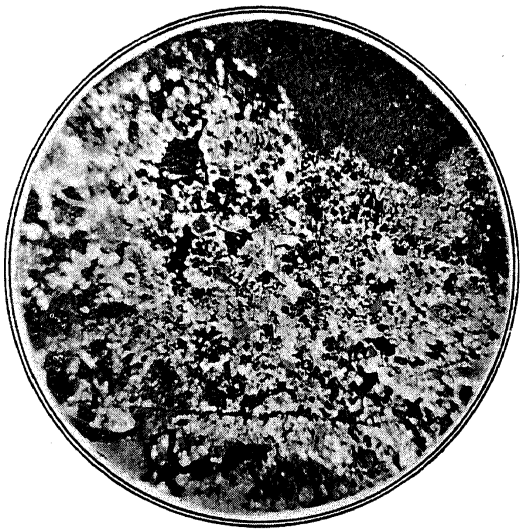

FIG. 6