

## DINOSAUR EGGSHELLS (SAURISCHIA) FROM THE LATE CRETACEOUS INTERTRAPPEAN AND LAMETA FORMATIONS (DECCAN, INDIA)

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**ABSTRACT**—Small eggshell fragments (from Takli 1 and Pisdura 2) or complete crushed eggs (Jabalpur) have been discovered in the intertrappean and Lameta beds from Deccan (India; Upper Cretaceous). Their microstructure is generally well preserved, allowing a fine interpretation of the eggshell pattern.

They are referred to sauropod dinosaurs because of their single-layered structure, with distinct growth units. These units are fan-shaped and thin for the first two localities. They show parallel radial limits for the last one and are slightly thicker. This attribution is also supported by the discussion on skeletal remains (bones or teeth) found in the same localities.

Prospecting in the sedimentary rocks between and below the basaltic flows from Deccan has been continued by an Indian-French team (listed in the acknowledgements) since 1980. Several localities have provided microvertebrate faunas, mainly in Takli 1 (Nagpur, Maharashtra), Pisdura 2 (Andhra Pradesh) and Jabalpur (Madhya Pradesh). In these faunas we found, mixed with the remains of microvertebrates, eggshell fragments and a few teeth. These are assigned to dinosaurs and they are the subject of this work.

The locality of Takli 1 (Gitti Khadan, Nagpur), between two lava flows, is typically intertrappean, and dated under the Paleocene–Upper Cretaceous boundary (Sahni et al., 1982a; Courtillot et al., 1986). Pisdura 2, in the upper part of the Lameta beds, is also considered as Upper Cretaceous, and has provided various bones of microvertebrates (Jain and Sahni, 1983, 1985) and large dinosaurs (von Huene and Matley, 1933). Jabalpur (=Jubbulpore) is also a classical Lameta site for dinosaurs (von Huene and Matley, 1933; Sahni and Gupta, 1982a).

### DESCRIPTION OF DINOSAUR EGGSHELL FRAGMENTS

#### Materials and Methods

The material has been collected at the surface of the outcrops (Jabalpur, Pisdura 2) or by washing and screening the marls and clays (Takli 1). In Takli 1, pieces of dinosaur eggshells are very rare (half a dozen specimens for 2 tons of sediment processed), and very small: the largest is 12 mm<sup>2</sup>. In Pisdura 2, more abundant material (14 eggshell fragments of 1 cm<sup>2</sup> area) has been previously described (Jain and Sahni, 1985). The following short description and figures are to be used

for comparison to the new material from Takli. Dinosaur eggshell fragments are more numerous in Jabalpur than in Takli 1 and Pisdura 2. These come from whole but crushed eggshells. For comparisons, we have also used specimens from the Rognacian deposits of Aix-en-Provence and Pont de Januc, Languedoc (France).

Frequently, the surfaces of the eggshell fragments are eroded, and sometimes impregnated with ferruginous alteration, as in TAK 1-1 (Fig. 3b).

The surfaces of the material have been observed by scanning electron microscope. Some fragments (tangential and radial sections) have been prepared with abrasive powders, then processed with acetic acid (5%, during 3'), to be observed by SEM (Fig. 6b, c). But we have mainly used radial and tangential thin sections (25 μm). The terminology used for the descriptions is given in Figure 1. The thickness of the eggshell fragments and the width of growth units have been measured on the radial thin sections (Table 1). Generally, it was not possible to give the exact height of the mammillary zone because the base of the spherulites is frequently damaged or not preserved.

#### Localities

**Takli 1** (Figs. 2a–c, 3a, b, 4a–e)—The eggshell fragments are thin (from 0.85 to 1.01 mm). The external surface (Fig. 2a) shows nodes of various diameters, well isolated, or, less frequently, linked. The pores are not visible on the surfaces. The internal face shows the bottom of growth units separated by broad valleys. Sometimes isolated, these bottoms are otherwise linked in groups or files of generally two or three units, sometimes four or more (Fig. 2b). Resorption craters are clearly marked on these specimens. Observed with the

SEM, the bottom of the spherulites (Fig. 2c) shows very thin calcite fibres (from 1 to 3  $\mu\text{m}$  thick). On radial thin sections the growth units are distinct, with a spherulitic bottom, fan-shaped, comparatively short and broad ( $H/W = 1.60$ ). The fan is widely opened, and well individualized when the growth unit fits a single node, more compressed and narrow when it is a part of a multiple node (Fig. 3a, b). The bottoms of the spherulites are generally damaged, and the tiny crystals are often missing. The tiny radiating fibres are easily visible, and clearly diverge from the growth center to the external surface of the node. A system of tangential growth striation overlays this system of radial striations. The growth striations, at first concentric above the spherulite, become progressively continuous from one to the other. They make broad undulations, convex in the growth unit, concave in the zone between two units (Fig. 4e). There is no true difference between a mammillary layer and a prismatic layer.

We have been able to section only one aerial canal (Fig. 4a–c). It appears to be narrow (from 5 to 8  $\mu\text{m}$  diameter) and proceeds straight through the thickness of the eggshell. It is broader at its outer border (25  $\mu\text{m}$ ) than on its inner one (15 to 25  $\mu\text{m}$ ).

The structure of the Takli 1 eggshells is organized into separate growth units, without any real horizontal differentiation, and with straight aerial canal. It corresponds to the single layered and tubocanalicular structure as described by Erben et al. (1979, fig. 1b). Until now, this structure has been observed only on northern Mediterranean dinosaur eggshells (Trepas Basin in Spain; Languedoc, Roussillon, Provence, in France). The structure of the Takli 1 eggshells is to be compared among the specimens from France to the fan-shaped growth unit type from the Upper Rognacian “Rousset Erben” site (Penner, 1985), and also to some specimens (Fig. 5c, d) recently found in the terminal Cretaceous deposits north of Montpellier (Languedoc) (Crochet, 1984:99).

**Pisdura 2** (Figs. 2d, 3c, 5a, b)—External and internal surfaces of the eggshell fragment, more or less eroded, show secondary calcite embedded between the units (Figs. 3c, 5a).

The thickness (from 1 mm to 2 mm, in Jain and Sahni, 1985) and the eggshell sculptures are the same as those of TAK 1-2 (Fig. 2d; Table 1). The growth units are short, stocky and fan-shaped ( $H/W = 1.31$ ). One of these units shows very well on the radial thin section, the center of growth and the tiny crystals (Figs. 5a, 3c). The divergent fibres are well marked, as well as the tangential growth striations. These striations are heavily convex in the “mammillary zone”, and then follow in continuous sinuous lines through the growth units of the “prismatic zone”. This specimen seems to be the same morphological type as in Takli 1.

**Jabalpur** (Figs. 2e–g, 3d, e, 6a, f)—The eggs were probably spherical, and their average estimated diameter is about 15 cm. The external and internal surfaces of the eggshells are often eroded and contaminated with secondary calcite which penetrates into the

separating surfaces between the growth units (Fig. 6a, e). It is difficult to determine if these areas are aerial canals or if they are merely a part of the canals filled with secondary calcite. Furthermore, the surfaces are also embedded by small grains of quartz. The eggshell is slightly thicker than those of Takli 1 and Pisdura 2 ( $H = 1.30$  mm). The width of the units is the same or perhaps a little bit smaller ( $W = 0.52$  mm), and these units seem more slender than the first ones ( $H/W = 2.5$ ).

On the best preserved fragments, the sculpture of the surfaces (Fig. 2e, f) can be observed and is very similar to those of Takli 1 and Pisdura 2. But in radial thin sections, differences appear between these eggshells. The growth units, well individualized, are more compressed laterally and slender (Fig. 3d) than those of the first two localities. Their shape recalls the shape of the first type of Penner (1985) (Fig. 1b), from the lower Rognacian of Provence, with their lateral limits almost parallel above the “mammillary zone” and their vaulted external limit (node).

One can observe such units (named by Erben, 1979 as “type A”) on a single radial thin section (Fig. 3d), which shows only divergent radial fibres and tangential growth striations. This thin section also shows units named “type C”, which exhibit a sort of “scaly” pattern that overlays the radial and tangential striations. This duality of pattern is also seen on a tangential thin section (Fig. 6e, f). We have made the same observations on different specimens from Roquehautes (Aix-en-Provence) (Figs. 3f, g, 7a). The scaly pattern seems to represent the marks of the cleavage planes of the calcite rhombohedra. The visibility of these plans depends on the orientation of the sections. Penner (1983: 171) made similar observations, and reached the same conclusion: there is no reason to separate two morphotypes (A and C) on this criterion.

The bottom of the growth units is generally not well preserved (Fig. 2f). However, with the SEM, it is possible to observe, some resorption craters on the inner surface of some specimens (Fig. 2g). The calcite fibres seem to be of the same size and same orientation as in the eggshell fragments from Takli 1 and Pisdura 2, and also as in the specimen from Aix-en-Provence figured (Fig. 2j). Like the latter, undulated tangential growth striations cross the fibres from one unit to the others. The contact between two units is almost perfectly straight. Along this contact, at different levels of the thickness of the eggshells, small spherulites appear, probably aborted extra growth units (Fig. 6a–d). This type of small accident also occurs on some eggshells from Southern France (Roquehautes, Aix-en-Provence) (Fig. 7b, c). In our specimens this pathological spots never leads to bi- or multistratified eggshells as in the pathologic eggshells from Provence. These eggshells are not frequent in Provence (2.5%; Kerourio, 1981). We have not studied all of the material from Jabalpur and we do not know any frequency of “pathological” eggshells from this locality. We have not ob-

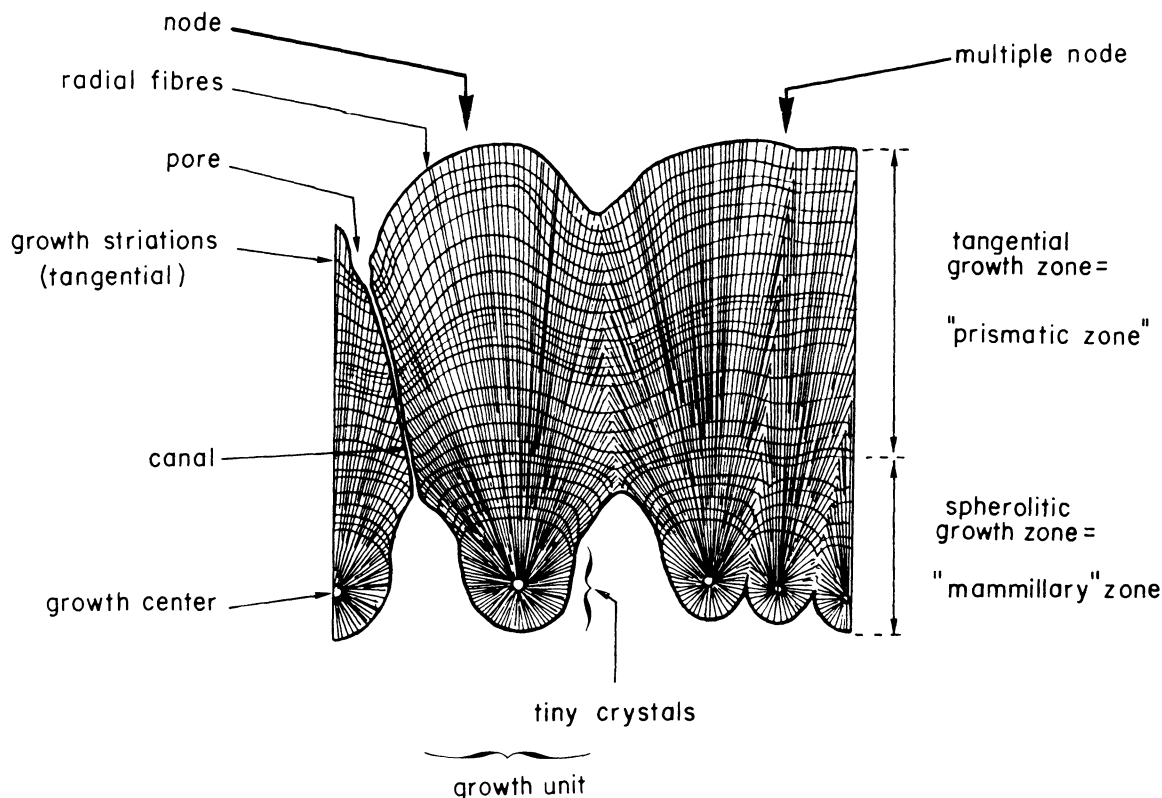


FIGURE 1. **Above**, terminology used here for the description of a dinosaur eggshell section; **right**, terminology used for the different types of dinosaur eggshell structures after Erben, 1970, Erben et al., 1979, Sochava, 1971, Penner, 1985.

served small extra growth units on the specimens from Takli 1 and Pisdura 2, but our sample was very small.

The contacts between the growth units, frequently at the confluence of three or four units, are sometimes eroded and enlarged. The resulting canal, of varied diameters, is often filled with irregular crystals of calcite (Fig. 6a, e). The bottom of the "mamillary zone" and the valleys between the nodes are often filled with such crystallisations (Figs. 3d, e, 6a). Some enlarge-

ments of these contacts between units could be aerial canals, but this is difficult to ascertain.

#### RELATIONSHIPS OF THE EGGSHELLS

All the Indian eggshells studied are thin and single-layered, with growth units well individualized, and vaulted on their external surface. India is the second country, after Europe, where this type of eggshell structure has been observed.

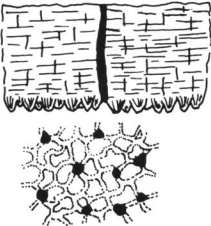
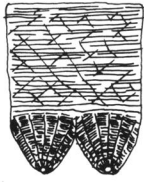

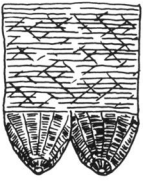

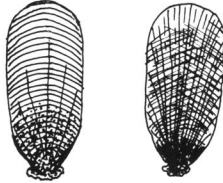


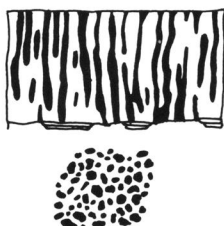
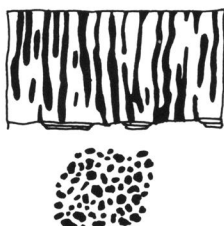
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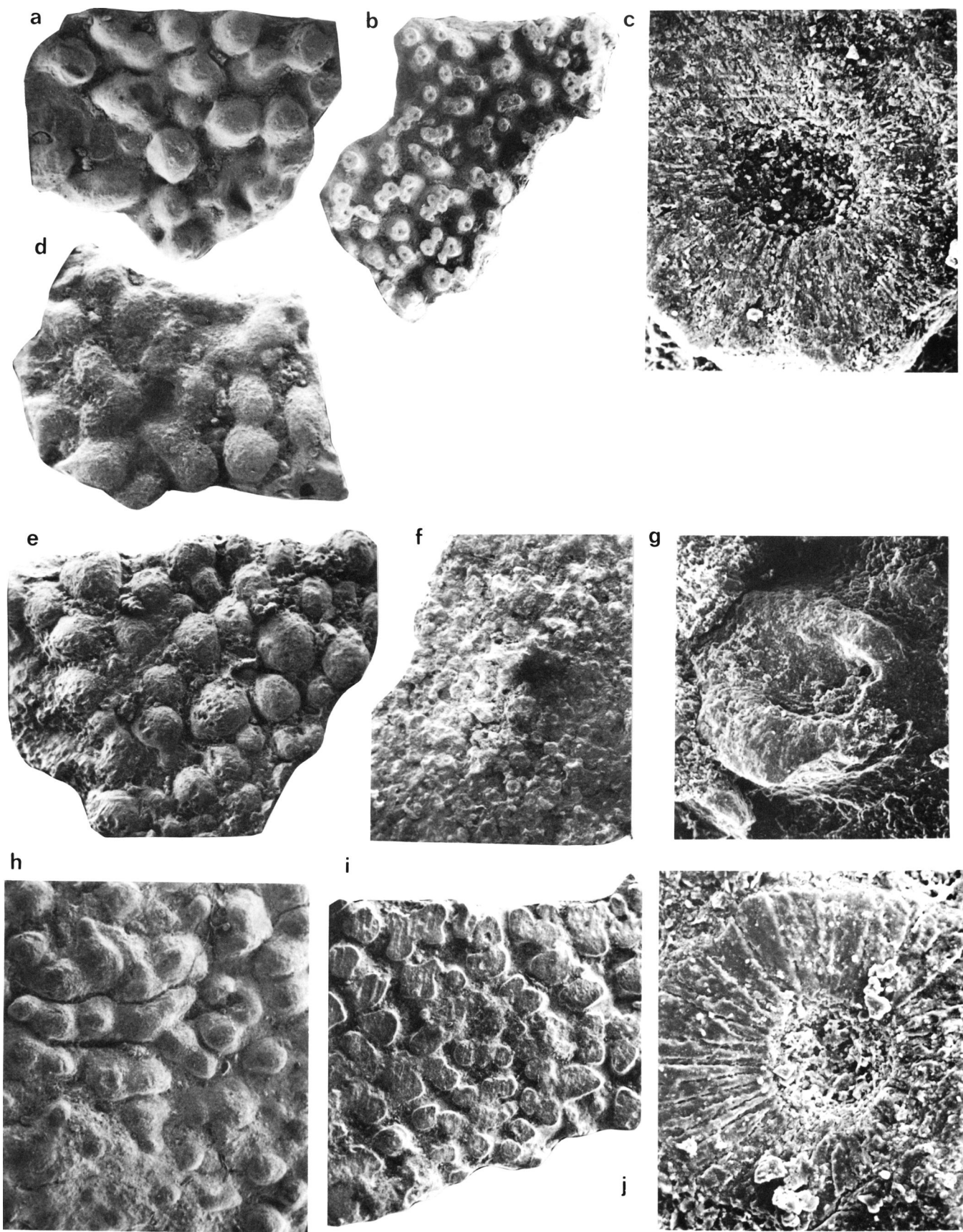
FIGURE 2. SEM photographs of the surfaces (inner and outer) of different dinosaur eggshells. **a**, outer surface, Takli 1, TAK 1-8,  $\times 14$ ; **b**, inner surface, Takli 1, TAK 1-9,  $\times 14$ ; **c**, resorption crater, inner surface, Takli 1, TAK 1-9,  $\times 420$ ; **d**, outer surface, Pisdura 2, PIS 2-2,  $\times 14$ ; **e**, outer surface, Jabalpur, JAB-5,  $\times 14$ ; **f**, inner surface, Jabalpur, JAB-6,  $\times 14$ ; **g**, resorption crater, inner surface, Jabalpur, JAB-6,  $\times 210$ ; **h**, outer surface, Roquehautes (Aix-en-Provence),  $\times 14$ ; **i**, inner surface, Roquehautes (Aix-en-Provence),  $\times 14$ ; **j**, resorption crater, inner surface, Roquehautes (Aix-en-Provence),  $\times 420$ .

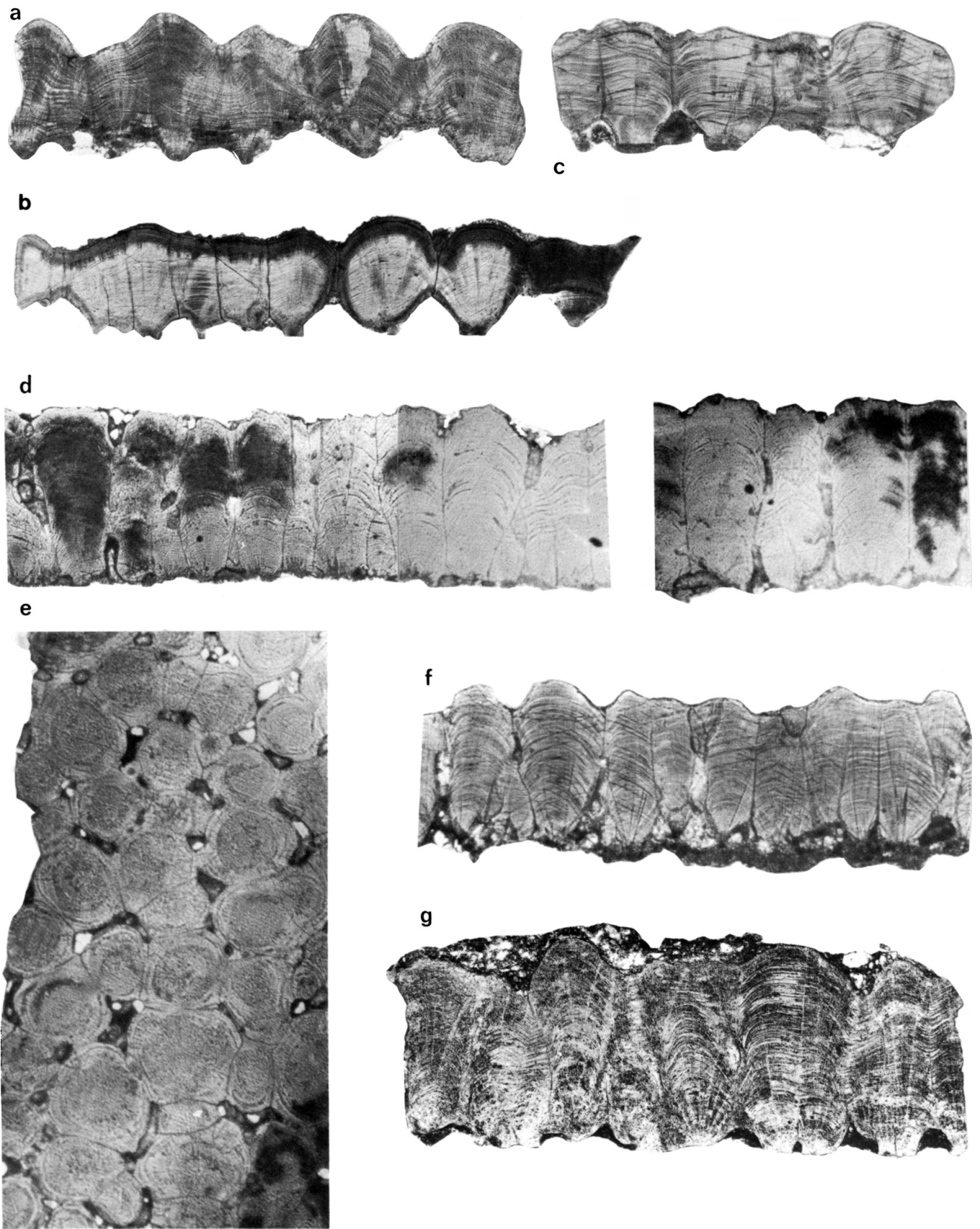
FIGURE 3. Thin section of dinosaur eggshells ( $\times 24$ ), polarized, radial (**a**, **b**, **c**, **d**, **f**, **g**) and tangential (**e**). **a**, TAK 1-2, Takli 1; **b**, TAK 1-1, Takli 1; **c**, PIS 2-1, Pisdura 2; **d**, JAB-1, Jabalpur; **e**, JAB-2, Jabalpur; **f**, Roquehautes (Aix-en-Provence) (type 3 of Penner); **g**, Aix-en-Provence (type 3 of Penner).

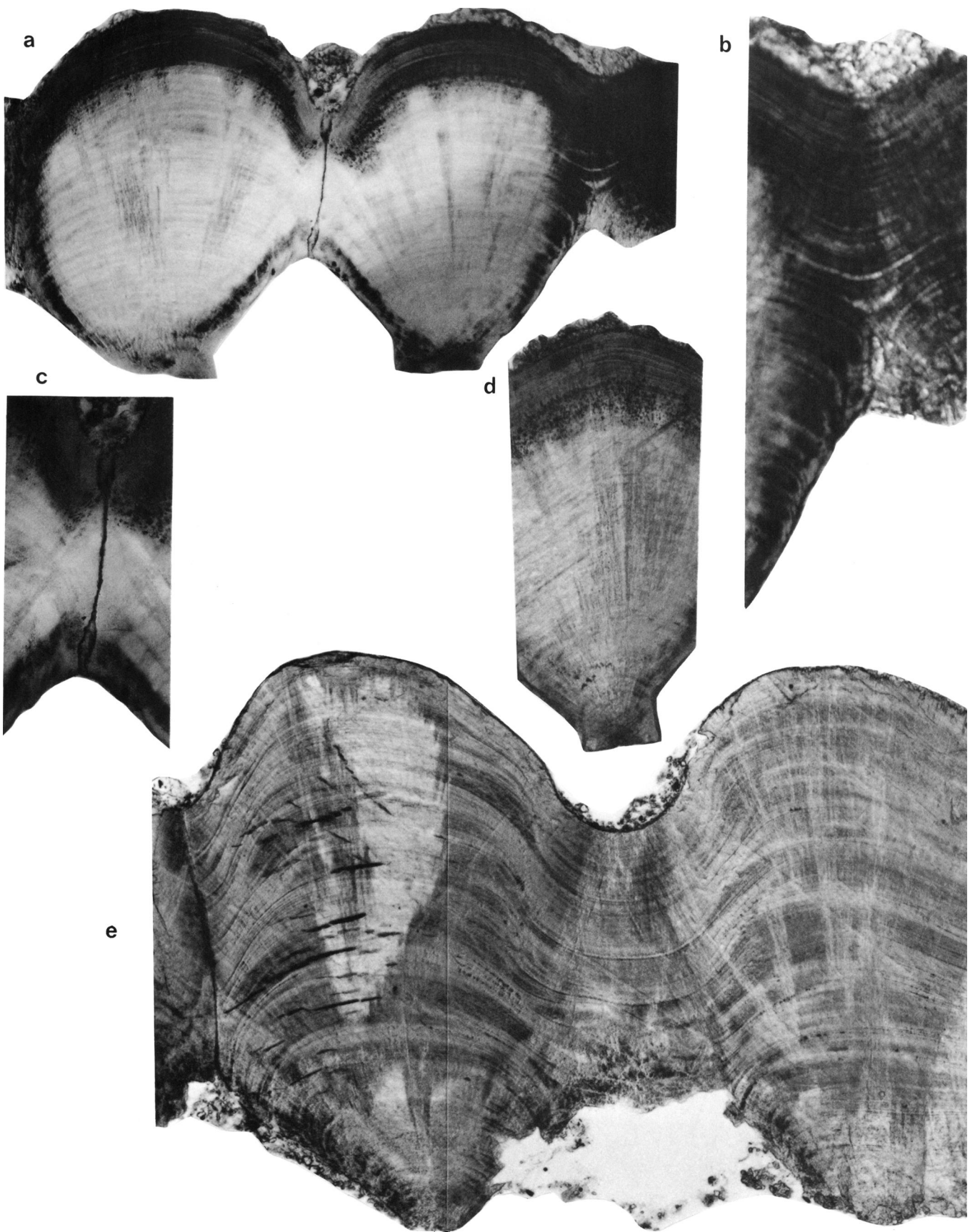
FIGURE 4. Radial thin section of the dinosaur eggshells from Takli 1 (Deccan, India), polarized. **a**, TAK 1-1, two fan-shaped growth units,  $\times 10$ ; **b**, the same,  $\times 20$ , showing the tangential growth striations continuous from one to the other unit; **c**, the same,  $\times 14.5$ , exhibiting an aerial canal; **d**, the same,  $\times 10$ , showing the spherulites and the radial calcite fibers; **e**, TAK 1-2, same explanation as **b**,  $\times 10$ .

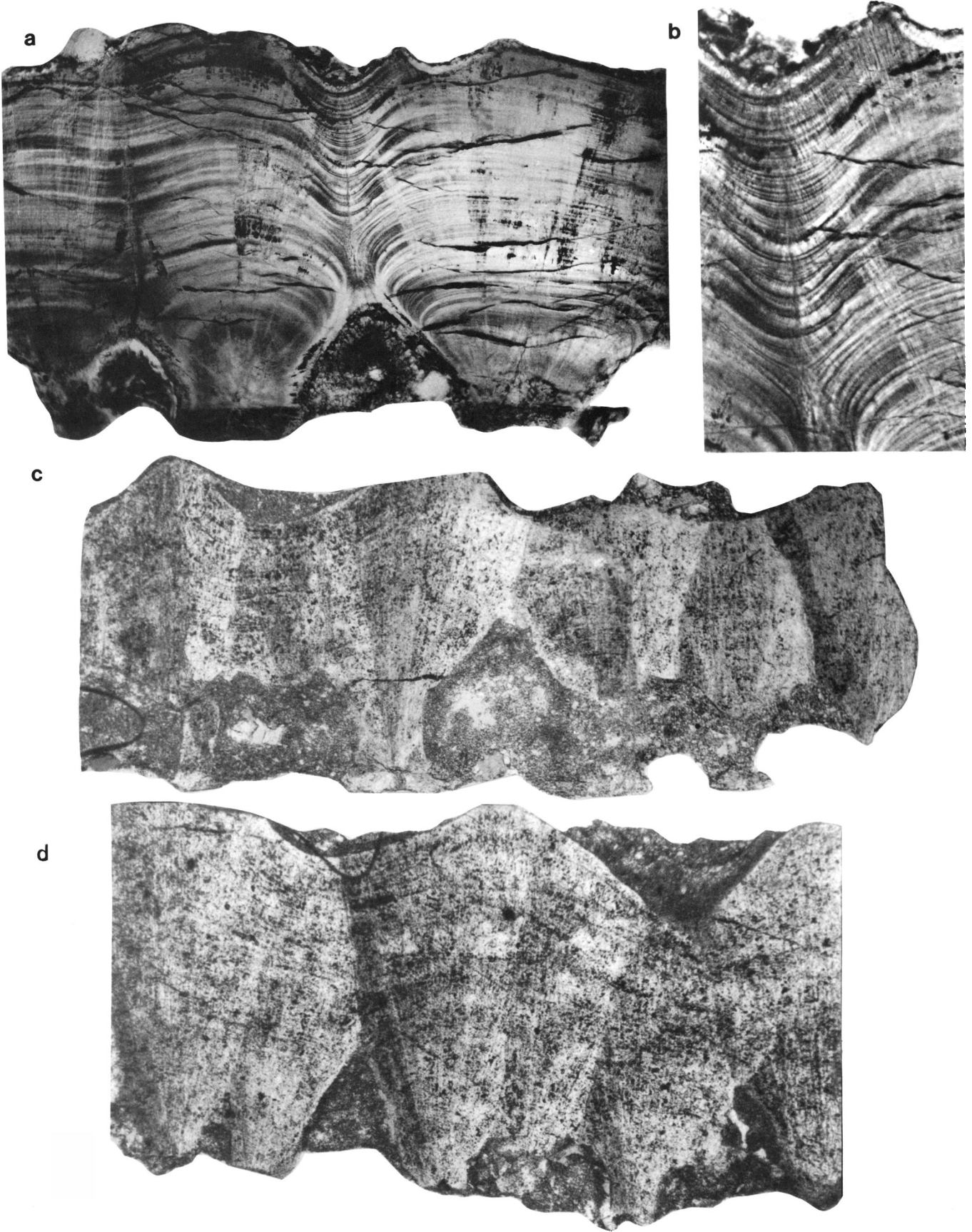
FIGURE 5. Radial thin section of the dinosaur eggshells from Pisdura 2 (Deccan, India) (**a**, **b**) and Pont-de-Januc (Hérault, France) (**c**, **d**), polarized. **a**, PIS 2-1,  $\times 10$ ; **b**, the same,  $\times 20$ ; **c**, (Penner type 3) PJA-1,  $\times 10$ ; **d**, (Penner type 3) PJA-2,  $\times 10$ .

"Taxonomic" attribution (Sochava)	Types:				Thickness (mm)	Localisation
	Sochava (1970-71)	Erben (1970)	Erben <i>et al</i> (1979)	Penner (1985)		
"ORNITHOÏDE" → ORNITHISCHIA	ANGUSTICANALICULATE = Erben' TYPE B (partim)				0,6-1,8 (Sochava)	Kazakhstan Gobi desert Shantung
						
"TESTUDOÏDE" → SAURISCHIA	PROLATOCANALICULATE = Erben' TYPE B (partim)				1,2-2,3 (Sochava)	Turonian-Cenomanian Gobi desert; Shantung?
						
"TESTUDOÏDE" → SAURISCHIA	TUBOCANALICULATE = Erben' TYPE A-C				1,8-2,5 (Erben)	Upper Maestrichtian FRANCE : Provence, Languedoc, Corbières SPAIN: Tremp Basin
						
	= Penner' TYPES	1 	2 			
? SAURISCHIA	MULTICANALICULATE				1,8 (Penner)	Above Rognacian limestones (Aix en Provence)
						
? SAURISCHIA	MULTICANALICULATE				2-2,5 (Sochava)	Albian-Cenomanian Gobi desert
						











The only reptiles showing similarities with this type of eggshell growth (one layer, growth units separated) are the chelonians. We have left aside the possibility that the Deccan eggshells are chelonian because the surfaces of chelonian eggshells are smooth and do not show nodes (see, for example, Fig. 8a-c).

The eggshells from Jabalpur are of a slightly different type from those of Pisdura 2 and Takli 1. With their parallel limits between units, they are close to type 1 of Penner (1985, fig. 1b), just a little thinner than the latter. The eggshells from Takli 1 and Pisdura 2 are close to those of the Upper Rognacian (type 3 of Penner, 1985), with their fan-shaped units. They are, however, thinner than those from Aix-en-Provence, but as thick as those from the terminal Cretaceous of Languedoc (Pont de Januc, Hérault) (Fig. 5c, d). The Aix-en-Provence dinosaur eggshells were at first only referred to the sauropod "*Hypselosaurus*" (Erben et al., 1979). More recent studies have shown that there are at least three saurischian morphological types (Penner, 1985) and one ornithoid type (Kerourio, 1982). These results agree better with the diversity of known skeletal remains: one carnosaur (*Megalosaurus pannoniensis*), two sauropods (*Hypselosaurus priscus* and *Titanosaurus indicus*), and one or two Ornithischia (de Lapparent, 1947; de Broin et al., 1980; Amiot et al., 1983).

The Cretaceous two-layered eggshells are referred to Ornithischia because the eggs associated with the skeletons of two genera of Ornithischia have a similar structure ("*Troodon*" and a hadrosaur from the Two Medicine Formation (Montana), as noted by Hirsch (in litt. to Penner, 1983 and Kerourio, 1982, with photographs), and also because of the analogy with the avian eggshell. The single-layered dinosaur eggshell is referred to the Saurischia (Soshava, 1969, 1971; Penner, 1983, 1985). It is surprising that, even though Saurischia are widespread all over the world, their eggs have been found only in restricted areas in the Late Cretaceous in Europe and in India. That is probably the result of the lack of systematic research (screen-washing fossiliferous sediments, for instance) of dinosaur eggshells. Generally, only very rich localities, with well-preserved eggs and nests, are studied. For example, in Penner's work (1983), there are 53 references about dinosaur eggshells. Twenty-three concern European eggshells, mainly those from Aix-en-Provence. Among the 28 others, four are relevant to South America, seven to North America, nine to Mongolia,

six to China, one to Africa, one to India. Among these 28 titles, complete eggs or nests make up the third of the specimens described. Sometimes, the diagenesis has completely obliterated the structure; then, any microstructural study is impossible. This is the case for the Uruguayan eggshells referred by Mones (1980) to *Saurischia* because of their general spherical shape. A more precise determination of these fragments needs an association of embryonic skeletal remains with the eggs. Here, the skeletal remains are rare in the studied localities, and there are no embryos. We can only give an idea of the associated fauna within which the dinosaur egg-layers could (or could not) be found.

Skeletal remains from Pisdura 2 have been determined by von Huene and Matley (1933) as sauropods of the family Titanosauridae (*Titanosaurus blanfordi*, cf. *T. indicus*, *Antarctosaurus* (?) sp., cf. *Laplatosaurus madagascariensis*).

In Takli 1, there are only a few teeth referred to three different Saurischia (see Figs. 9, 10).

In Jabalpur, the skeletal remains have been referred by von Huene and Matley (1933) to 15 species of Saurischia and one of Ornithischia as follows:

#### Saurischia

Sauropoda, Titanosauridae: *Titanosaurus indicus*, cf. *T. indicus*, cf. *Titanosaurus* sp., *Antarctosaurus septentrionalis*, cf. *Antarctosaurus* sp., aff. *Titanosaurus* gen. indet.

Carnosauria, Allosauridae: *Indosuchus raptorius*, *Indosaurus matleyi*

Coelurosauria, Compsognathidae: *Compsosuchus solus*

Coeluridae: *Laevisuchus indicus*, *Jubbulpuria tenuis*, *Coeluroides largus*, *Dryptosauroides grandis*

Ornithomimidae: *Ornithomimoides mobilis*, *O. (?) barasimlensis*

#### Ornithischia

Stegosauridae: *Lametasaurus indicus*.

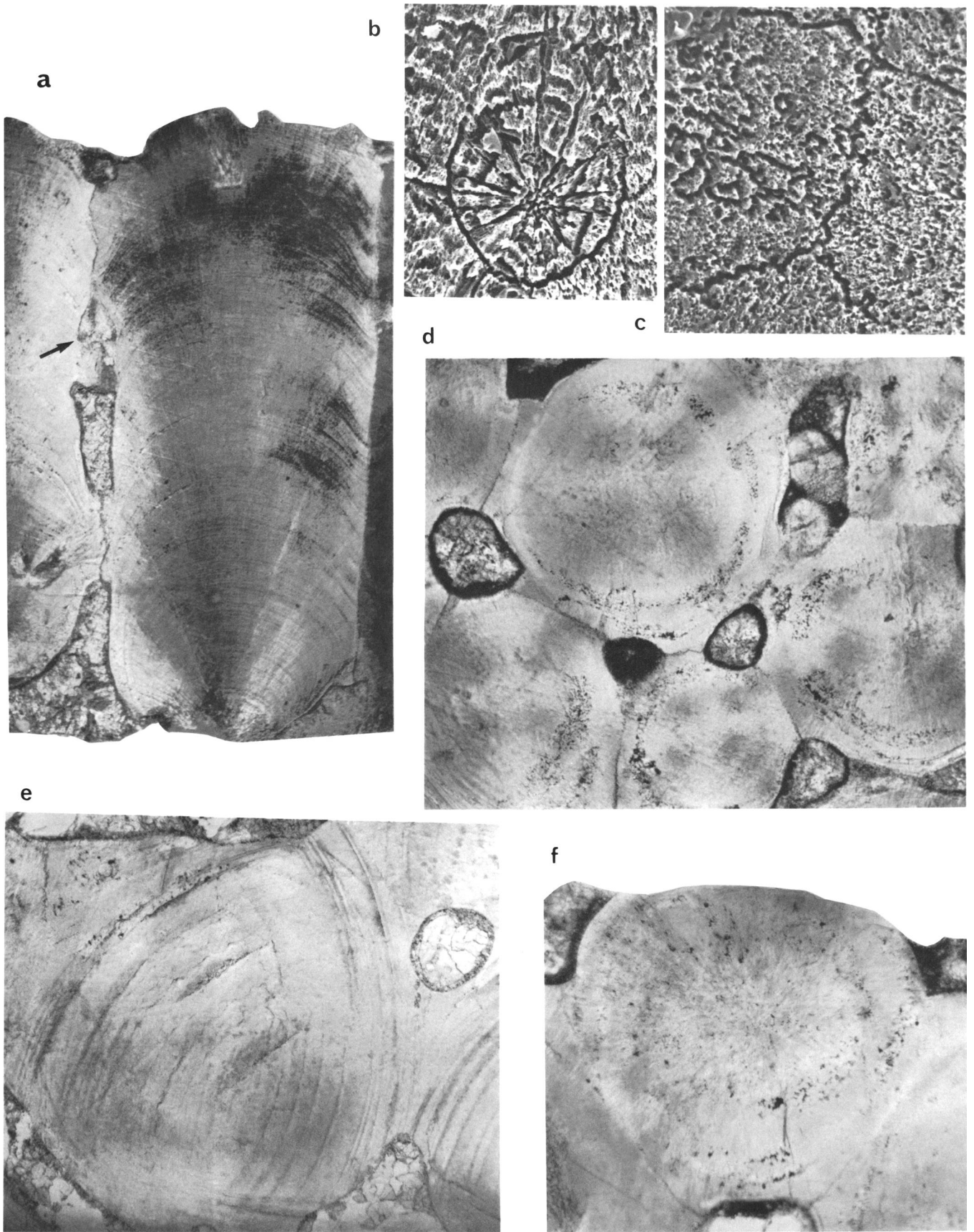
The greater number of these taxa comes from Bara Simla Hill, near Jabalpur (Fig. 11a). The sauropod beds have provided the most abundant and most complete remains of *Titanosaurus indicus* (tibia, fibula, vertebrae) and of *Antarctosaurus septentrionalis* (scapula, humerus, radius, ulna, ribs, vertebrae, piece of skull) representing at least three, and perhaps five individuals, according to von Huene and Matley (1933).

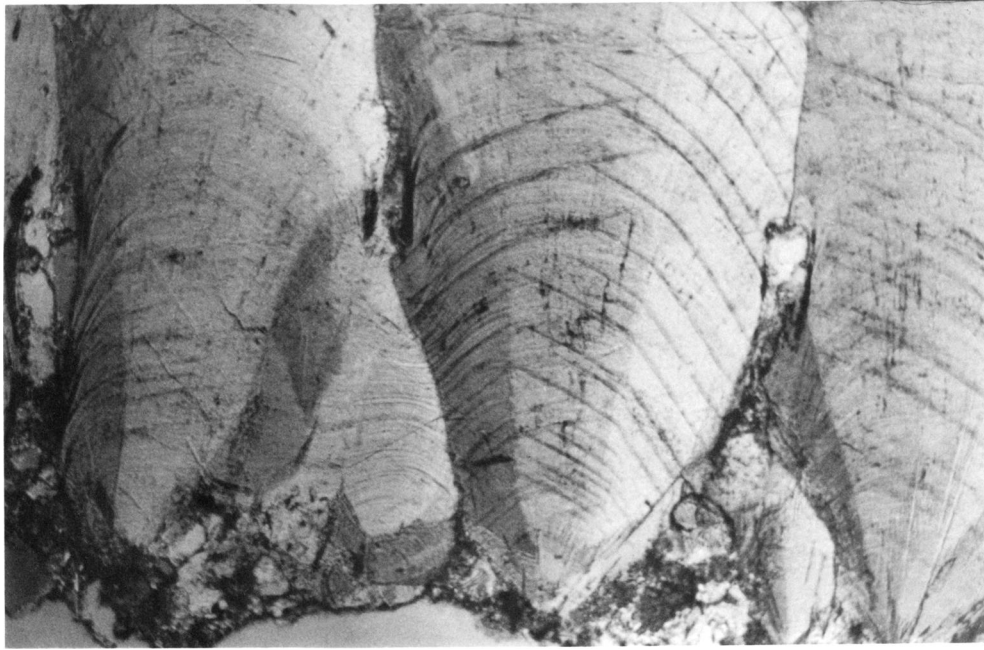
In the carnosaur beds, the titanosaurids are rare, the

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FIGURE 6. Dinosaur eggshells from Jabalpur (Deccan, India) (polarized). **a**, radial thin section showing the radial and tangential growth striations, extra growth units at the limit of the units, or at the base of the left unit,  $\times 10$ ; **b**, SEM photograph of a radial section showing an extra growth unit,  $\times 340$ ; **c**, SEM photograph of a tangential section showing the limits of the units; **d**, tangential thin section showing "pores?", extra-growth units in some of these "pores",  $\times 10$ ; **e**, tangential thin section of a unit showing the cleavage plans of the calcite,  $\times 20$ ; **f**, the same, showing the radial fibers of calcite,  $\times 20$ .

FIGURE 7. Radial thin sections of two types of dinosaur eggshells from Aix-en-Provence. **a**, (Penner type 3) growth units showing radial and tangential growth striations and the cleavage plans of the calcite ( $\times 10$ ); **b**, (Penner type 1) growth units with extra spherulites ( $\times 10$ ); **c**, the same, ( $\times 30$ ).





**a**



**b**



**c**

TABLE 1. Measurements of fossil eggshells from India.

H	Takli 1-A				Takli 1-B				Pisdura 2				Jabalpur						
	H̄	W	W̄	H̄/W̄	H	H̄	W	W̄	H̄/W̄	H	H̄	W	W̄	H̄/W̄	H	H̄	W	W̄	H̄/W̄
0.82	1.01	0.48	0.63	1.60	1.19	0.85	0.32	0.52	1.63	0.91	0.88	0.67	0.67	1.31	1.27	1.30	0.53	0.52	2.50
0.88	0.53	0.53	0.80	0.80	0.80	0.18	0.18	0.87	(0.82)	0.87	(0.94)	0.47	0.47	1.22	1.22	0.47	0.47	0.47	0.47
1.12	0.55	0.55	0.69	0.69	0.54	0.54	0.91	0.91	0.54	0.91	0.54	0.54	0.54	1.42	1.42	0.53	0.53	0.53	0.53
1.05	0.79	0.79	0.81	0.81	0.30	0.30	0.81	0.81	0.38	0.81	0.38	0.38	0.38	1.43	1.43	0.64	0.64	0.64	0.64
1.15	0.82	0.82	0.76	0.76	0.38	0.38	0.53	0.53	0.38	0.38	0.38	0.38	0.38	1.43	1.43	0.47	0.47	0.47	0.47
1.03			0.80	0.80	0.53	0.53	(1.28)	(1.28)	0.86	0.86	0.86	0.86	0.86	1.36	1.36	0.59	0.59	0.59	0.59
			0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	1.26	1.26	0.44	0.44	0.44	0.44
			0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	1.35	1.35	0.50	0.50	0.50	0.50
														1.12	1.12	0.41	0.41	0.41	0.41
														1.13	1.13	0.38	0.38	0.38	0.38
														1.30	1.30	0.40	0.40	0.40	0.40
														1.35	1.35	0.69	0.69	0.69	0.69
														1.25	1.25	0.63	0.63	0.63	0.63
														1.12	1.12	0.49	0.49	0.49	0.49
														1.20	1.20	0.44	0.44	0.44	0.44
														1.20	1.20	0.57	0.57	0.57	0.57
														1.30	1.30	0.50	0.50	0.50	0.50
														1.47	1.47	0.46	0.46	0.46	0.46
														1.35	1.35	0.65	0.65	0.65	0.65
														1.31	1.31	0.61	0.61	0.61	0.61

H = height of a growth unit = thickness of the eggshell.  
H̄ = average height.  
W = width of a growth unit.  
W̄ = average width.  
H̄/W̄ = average radial lengthening ratio of the growth units.

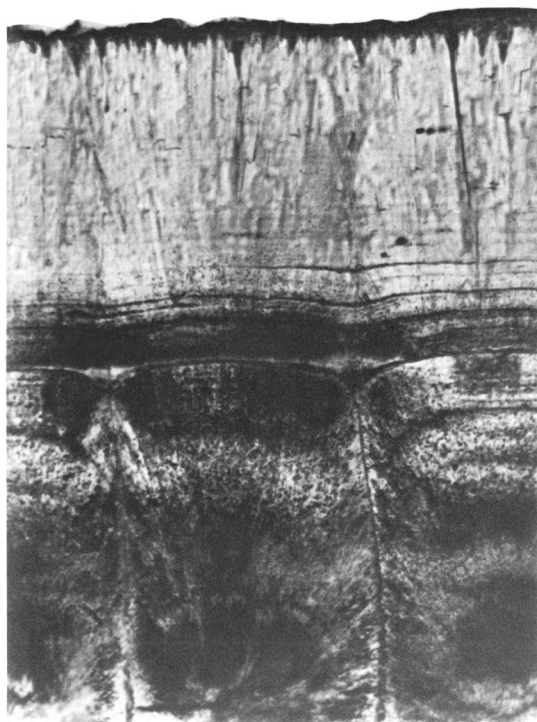
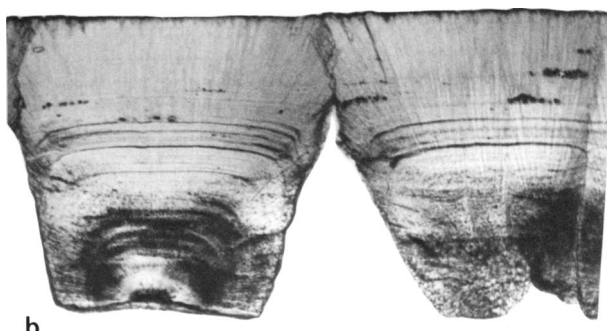
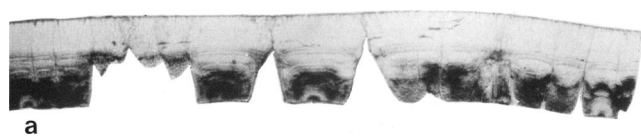


FIGURE 8. Eggshells of *Tesdudo elephantina* showing the growth units with large spherulitic zone, "vertical" crystals and the horizontal growth plans, and the smooth external surface. a,  $\times 24$ ; b,  $\times 80$ ; c,  $\times 200$ .

main part of the bones are referred to the Allosauridae (carnosaurs) or to coelurosaurids. Among these remains, the Allosauridae are the most numerous (several fragments of skulls). The seven species of coelurosaurids are identified on one to ten pieces of vertebrae!

The eggshells have been discovered on the opposite side of Bara Simla Hill from the skeletal remains, in a grey sandstone that is absent in the old quarry. This level of thin sandstone, situated about 20 m under the lava flow, could be a lateral equivalent of the lower part of the mottled nodular beds. It is impossible (because of presence of a military zone) to know precisely if this level is the same of the sauropod bed, or if it lies above it.

The spherical shape of the eggs and their large size could support their assignation to a sauropod (*Titanosaurus* or *Antarctosaurus*), which are abundant in the sauropod bed.

#### DINOSAUR TEETH FROM TAKLI 1

The difficulties of dinosaur tooth studies come from the lack of systematic and detailed works on these structures. The dentition of dinosaurs has never been especially studied, and no detailed key exists for discriminating taxa on dental criteria. However, we have tried to assess their dinosaurian nature, and, when possible, to give a more precise taxonomic attribution. It could give us an idea of the possible egg-layers in Takli 1.

In Takli 1, the only skeletal specimen identified is a tooth referred by Lydekker (1880) to *Massospondylus rawesi*. The genus *Massospondylus* (Anchisauridae, Marsh 1885; Steel, 1970:47) is defined on skeletal remains from the South-African Upper Triassic. It is also known from some skeletal and dental remains from Maleri beds (Upper Triassic, India), with the species *M. hislopi* (Lydekker, 1880). When Lydekker described the tooth from Takli 1, he underlined some similarity between it and the Maleri tooth, although it is more compressed and acute. He referred to it as a new species of the same genus and considered it as a theropod anchisaur. He mentioned that it is the first record in the Late Cretaceous of this mainly Upper Triassic family. Lydekker believed that this tooth could not come from the Takli intertrappean beds (because they were considered as Eocene in age) but must have come from the Cretaceous Lameta beds ("... infra-trappean Lameta beds do occur at Takli beneath the intertrappeans."). Our field work has shown that only intertrappean beds occur on Takli hill, and they contain dinosaurian remains. So it is probable that the tooth of *M. rawesi* comes from the intertrappeans of Takli.

On the other hand, the tooth morphology (relatively large size: H = 30 mm, L = 14 mm; serrated arched blade, with numerous serrations) is rather of a true carnosaur in morphology than of an anchisaurid, this last family belonging to the prosauropods (Steel, 1970). Because of the close similarity to the teeth of *Megalosaurus crenatissimus* (Depéret, 1896) from the Cretaceous of Malagasy, we prefer to transfer the tooth of Takli from the genus *Massospondylus* to the genus *Megalosaurus*. Whether the species name *rawesi* is valid, or if it is synonymous with *crenatissimus* or some

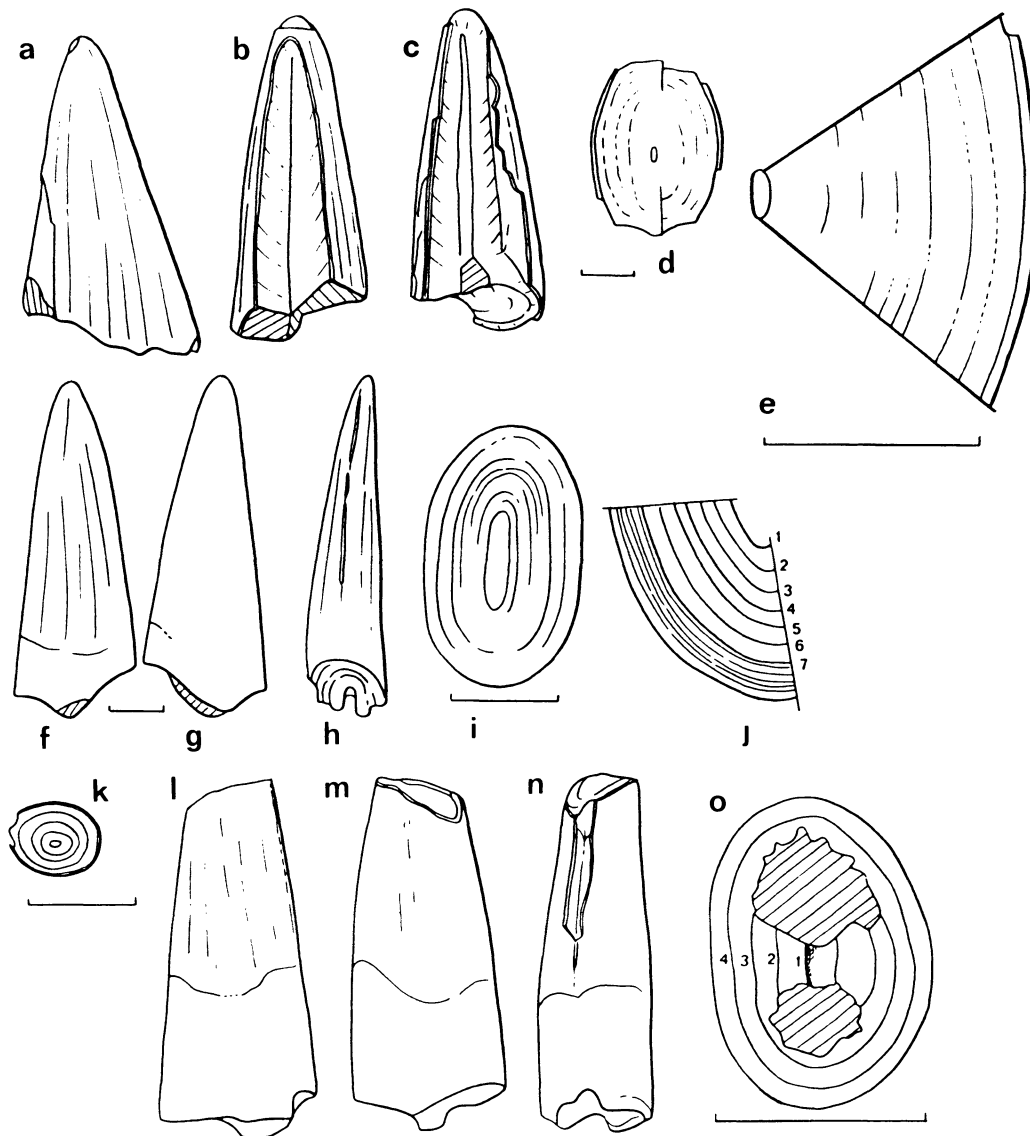


FIGURE 9. Conical teeth from Takli 1. **a**, TAK 1-3, sauropod ?, lateral view; **b**, the same, mesial (?) view; **c**, the same, distal (?) view; **d**, section of the tooth; **e**, the same, enlarged, showing very weak growth rings; **f**, TAK 1-4, Saurischia indet. or Crocodilia, lateral (anterior ?) view; **g**, the same, lateral (posterior ?) view; **h**, the same, mesial (or distal) view; **i**, the same, section of the tooth; **j**, the same, showing seven growth rings; **k**, TAK 1-5, Saurischia indet. or Crocodilia, section of the apex of the tooth; **l** and **m**, the same, lateral views; **n**, the same, mesial (or distal) view; **o**, the same, section of the tooth showing four growth rings. The scale represents 1 mm.

other species, is unknown. In this situation we retain the name *Megalosaurus rawesi*.

Screen-washing of the fossiliferous marls (Fig. 11b) from Takli 1 produced five teeth possibly referable to dinosaurs (Figs. 9, 10). None shows any similarity to ornithischian teeth. Three are slightly conical. The largest (TAK 1-3; H = 6.2 mm; L = 3.3 mm; W = 2.5 mm) is only the apex of a tooth. The thin enamel bears very weak striations. Two opposite faces (mesial and distal?) show heavily worn surfaces, just like those which can be observed on some sauropods, e.g. *Asiatosaurus* (Osborn, 1924). However, this tooth is not spatulate

as in many sauropods, but has an oval section. The attribution of the two other conical teeth to dinosaurs is more questionable. TAK 1-4, smaller than TAK 1-3 (H = 6.9 mm; L = 2.3 mm; W = 1.5 mm) shows no wear facet. It is extremely eroded, and enamel has almost disappeared. A ridge is still recognized on a (mesial?) face of the tooth. Like TAK 1-3, the section of the tooth is oval, but more compressed labio-lingually. The dentine shows distinct growth rings. These rings are weak and badly marked on TAK 1-3 but are very well developed on TAK 1-4, and also TAK 1-5, like those observed by Johnston (1979) on tyranno-

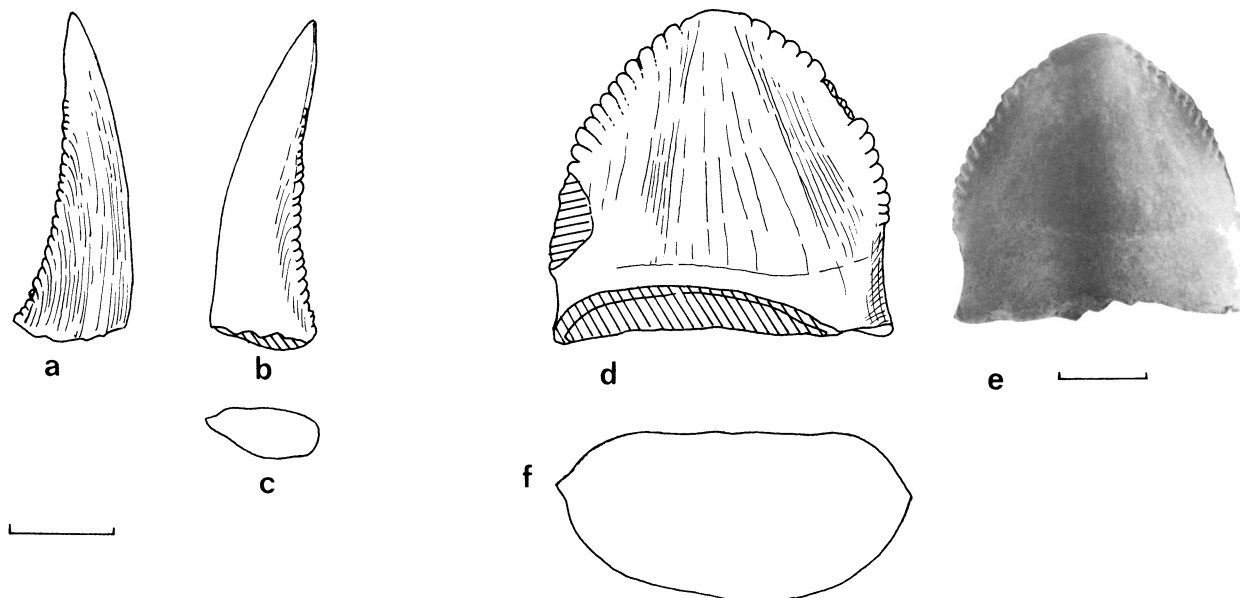


FIGURE 10. Serrated teeth from Takli 1 (Coelurosaurian ?). **a** and **b**, TAK 1-6, lateral views; **c**, the same, section of the tooth; **d** and **e**, TAK 1-7, lateral views; **f**, the same, section of the tooth. The scale represents 1 mm.

saurid and crocodile teeth. TAK 1-4 shows at least seven concentric rings (the center of the tooth is damaged) like those interpreted as seasonal annual rings by Johnston. The break corresponds to a narrow band and the ring to a broad band (Johnston, 1979, fig. 1, n.b. and b.b.). In each broad band occur fine concentric striations, the contour lines of Owen (Johnston, 1979), linked to minor physiological variations. TAK 1-5 shows only four annual growth rings. This tooth, better

preserved, shows a general shape like TAK 1-4, but it is smaller (H = 3.1 mm; L = 1.5 mm; W = 0.9 mm).

The last two teeth, TAK 1-6 and TAK 1-7, can be more certainly referred to small carnivorous dinosaurs, because of the asymmetrical labio-lingual compression of the crown and the serrations on the mesial and distal edges. TAK 1-6 is the largest one (H = 2.44 mm; L = 3.36 mm; W = 1.55 mm). It is low for a carnivorous dinosaur, and its mesio-distal profile symmetric. Each

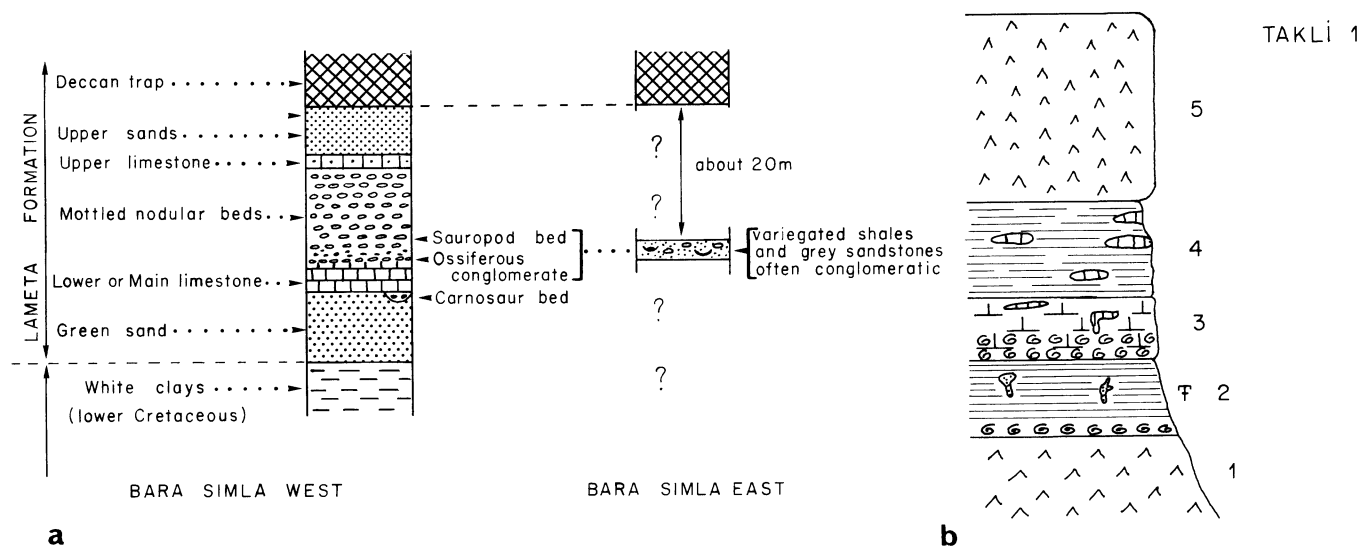


FIGURE 11. **a**, sedimentary sequence of Jabalpur (Deccan, India) and dinosaur localities. Bara Simla West, after von Huene et al., 1937 (scale about 1:1000). **b**, sedimentary sequence of Takli 1 (Nagpur, Deccan, India); **1**, basalt (lower lava flow); **2**, green clays, with calcareous burrows, crushed gastropod shells; **3**, grey marls, with calcareous nodules, complete recrystallized gastropod shells; **4**, green and grey marls with centimetric calcareous cells; **5**, basalt (upper lava flow).

lateral edge bears 17 flat serrations set at right angles. One of the faces (labial or lingual) is convex, the other is flattened. TAK 1-7 is arched: the convex border (mesial?) is rounded, without any serration, the concave one, compressed, forms a ridge bearing the flat serrations. The size of these serrations decreases toward the upper part of the crown; they disappear about two-thirds of the length of the edge. These 23 serrations are smaller than those of TAK 1-6.

The serrated, arched and compressed teeth are generally referred to carnivorous saurischians, coelurosaurians, or carnosaur. The large teeth are referred to carnosaur (for instance to Megalosauridae). The small ones are assigned frequently to coelurosaurians. Growth and continuous tooth replacement may bring some confusions between these classes. Thus, and because of the small size of our sample (TAK 1-6, 1-7), it will be referred to small theropods, without any more precision.

On the basis of the teeth, the Takli 1 locality could contain remains of at least three species of Saurischia: one sauropod, one or two small coelurosaurians (?), and one carnosaur (Megalosauridae).

### CONCLUSIONS

Systematic research for microvertebrates in the Decan intertrappeans (presumed Paleogene), had as its first goal the documentation of the initial Tertiary mammalian population of India. It gave us unexpected results. These intertrappeans were chronologically situated under the Cretaceous-Paleocene limit and provided dinosaur remains, pieces of eggshells and teeth. The morphological and microscopical analysis of the eggshells from three sites (Takli 1, Pisdura 2, Jabalpur) allow the reference of these dinosaurs to probably sauropod Saurischia.

This assignment is made on the basis of the single-layered eggshell, with distinct growth units, which until the Indian discoveries, was known only from Upper Cretaceous European localities. If this structure is in fact characteristic of the whole group of Saurischia, and not only of a particular taxonomic unit, there is no reason why it should not occur in other regions where the Saurischia are known. A more systematic investigation of sediments in these regions should lead to a considerable increase of the fossil dinosaur eggshell and tooth record. The five teeth discovered in Takli 1 show a larger diversity of the dinosaur fauna (sauropod?, theropod, ind., carnosaur) than that indicated by the few eggshell remains.

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#### BRYAN PATTERSON PRIZE

The recipient of the 1987 Bryan Patterson Prize for the best student proposal for paleontological field work is Gregory A. Buckley (Department of Geology, Rutgers University) for his proposal entitled "Biostratigraphy, Lithostratigraphy, and Magnetostratigraphy of the Early Paleocene Bear Formation, Crazy Mountain Basin, Montana."