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Silicified megaspores from Upper Cretaceous beds of southern Alberta, Canada

ABSTRACT
Silicified megaspores with well-preserved wall structure have been recovered from Upper Cretaceous bentonitic shales of southern Alberta. Two new genera are proposed. Nine new species belonging to five form genera, viz. *Henrisporites, Verrutriletes, Horstisporites, Stelckisporites,* new genus, and *Selenasporites,* new genus, are described. *Henrisporites* and *Verrutriletes* are suitably emended.

INTRODUCTION

Contemporary palynological techniques for the extraction of specimens are based primarily on dissolving the silicate and carbonate contents of the samples. Hence records of silicified or calcified spores are rare in palynological literature. Sahni and Rao (1943) described silicified megaspores and microspores in thin sections from the Intertrappean cherts of the Deccan in India. Sitholey (1943) described the siliceous casts of megaspores from the Triassic of the Salt Range in the Punjab under the genus *Triletes.* Due to difficulties in isolating the microspores from the cherts, Rao (1943) and Vishnu-Mittre (1954) described from thin sections a silicified microflora from Jurassic rocks of the Rajmahal Hills, Bihar, India.

In the course of a micropaleontological investigation of Upper Cretaceous beds in southern Alberta, shale samples were treated with a standard technique for the recovery of foraminifera. During this process, a number of isolated silicified megaspores with fully preserved structure and ornamentation were found, and they are described in the present study. To the writers' knowledge, this is the first record of isolated silicified megaspores with well-preserved wall structure.

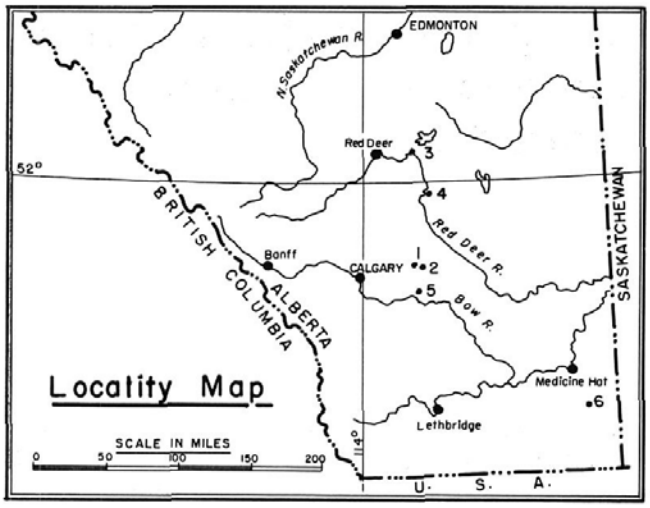
TECHNIQUE

One hundred grams of each sample were soaked in water with 2 grams of detergent until disaggregation of the shale occurred. The average time was 48 hours. The clay was further dispersed by agitation for 3 minutes in a blender. The material was passed through a set of three sieves with openings of respectively 250, 147 and 74 microns. The residues collected on each sieve were dried separately in an oven. Megaspores were picked out by examination under a binocular microscope. The type specimens of species described herein are deposited with the Department of Geology, University of Alberta, Edmonton.

LOCALITIES

The specimens described come from samples taken from outcrops in the following localities, shown in text-figure 1 :

Loc.	Section	Township	Range west of 4th meridian
1	30	24	22
2	28	24	22
3	5	39	22
4	18	34	21
5	13	22	24
6	9	8	4



TEXT-FIGURE 1
Map of southern Alberta showing sample localities.

In the first five localities listed above, the microfossils were recovered from the Kneehills tuff zone (Ower, 1960) of the Edmonton Formation, while in Locality 6 they were found in the Battle Formation (Furnival, 1946). The two stratigraphic units were systematically sampled with one sample taken every meter from bottom to top.

GEOLOGY

The Edmonton Formation covers much of Alberta east of the Foothills and south of latitude 56°. Lithologically it consists of sandstones, siltstones, shales and several coal seams. It is Upper Cretaceous in age, and its thickness varies from 1000 to 1200 feet on the plains up to 2500 feet in the foothills (Hargreaves *et al.*, A.S.P.G. Lexicon, 1960). Ower (1960) divided the Edmonton Formation into five members, *viz.*, A, B, C, D and E from bottom to top, calling the Kneehills tuff zone the D member. This member is 20 to 50 feet thick and has been defined as: "Black to brown bentonite shale, containing purplish shale and thin tuff bands near top; often white clay shale and bentonitic clayey white sand at base". Bentonites from the Kneehills tuff zone have yielded a radiogenic age of 66 million years (Folinsbee, Baadsgaard and Lipson, 1961).

The Battle Formation, which outcrops in the Cypress Hills of southern Alberta and southwestern Saskatchewan, has been correlated with the Kneehills tuff zone on the basis of lithological similarities and stratigraphic position (Allan and Sanderson, 1945). This unit is underlain by the Whitemud Formation, containing a Maestrichtian flora, and overlain by the Frenchman Formation, which bears a Danian flora (Bell, 1949).

SYSTEMATIC DESCRIPTION

The frequent existence of morphological variation even in megaspores of the same species leads many workers to place all of the megaspore forms in the single genus *Triletes*. It has been felt that a purely morphographic classification does not justify the known biological relationships. However, a more serious error creeps in by grouping all megaspores under one genus, and this procedure does not serve any taxonomic or stratigraphic purpose. Therefore, the criteria for the classification of megaspores followed here are the same as those adopted by Singh (1964).

Genus ***Henrisporites*** Potonié, 1956, **emend.** Binda and Srivastava

Type species: Henrisporites affinis (Dijkstra) Potonié, 1956.

Diagnosis: Megaspores trilete, zonate; amb subtriangular to triangular; tetrad mark reaching the equatorial outline of the zona; arms higher than their breadth, sometimes very high; proximal and distal surfaces with sparse granulate to spinate ornamentation.

Remarks: Potonié (1956) has described the genus *Henrisporites* as having sparse coni grading into spines and wrinkled exine. Here the genus is emended to include all zonate trilete megaspores having a raised tetrad mark, granulate to spinate ornamentation, and exine with or without wrinkles.

Henrisporites granulatus Binda and Srivastava, **n. sp.**
Plate 1, figures 1–6

Description: Megaspore trilete, plano-convex, zonate; zona 20 microns wide; tetrad mark prominently raised; arms of the tetrad mark 20 microns wide, extending to the equatorial outline of the zona, about 15 microns thick; amb subtriangular with convex sides; proximal surface smooth with concave interradial areas; distal surface granulate; granules 10 to 12 microns wide at the base.

Size: Equatorial diameter 360 microns.

Holotype: Locality 6; Slide No. BS2/31; plate 1, figures 1–3.

Remarks: H. granulatus differs from other similar megaspore species of the genus *Henrisporites* in having granulate ornamentation.

Henrisporites elkwaterensis Binda and Srivastava, **n. sp.**
Plate 1, figures 7–11

Description: Megaspore trilete, biconvex, zonate; zona 20 to 25 microns wide; tetrad mark prominently

raised, extending up to the margin of the zona; arms of the tetrad mark about 40 microns wide; amb subtriangular with convex sides; proximal surface moderately verrucose; verrucae about 25 microns in diameter; on the distal surface verrucae densely packed and often fused together to form a rugate pattern.

Size: Equatorial diameter 480 microns.

Holotype: Locality 6; Slide No. BS2/29; plate 1, figures 7–9.

Remarks: H. elkwaterensis has verrucose ornamentation and is larger than *H. granulatus*. The trivial name is taken from the town of Elkwater, Alberta.

Henrisporites sheilae Binda and Srivstava, **n. sp.**
Plate 2, figures 1–3

Description: Megaspore trilete, biconvex, zonate; zona about 15 microns wide; tetrad mark well defined and raised, extending up to the margin of the zona; arms of the tetrad mark 25 to 30 microns wide; amb subtriangular with convex sides; proximal and distal surfaces rugate; rugae 25 to 30 microns wide.

Size: Equatorial diameter 370 microns.

Holotype: Locality 1; Slide No. BS1/33; plate 2, figures 1–3.

Remarks: The trivial name has been bestowed in appreciation of the assistance given by Mrs. Sheila M. Binda, wife of the senior author.

Genus ***Verrutriletes*** van der Hammen, 1954, ex Potonié, 1956, **emend.** Binda and Srivastava

For synonymy see Singh (1965)

Type species: Verrutriletes compositipunctatus (Dijkstra) Potonié, 1956.

Diagnosis: Megaspores trilete; equatorial and meridional outline circular to subtriangular; trilete rays may or may not reach the equator; ornamentation verrucose to conate; in some species verrucae fused at the base; proximal surface smooth or ornamented.

Remarks: The genus *Verrutriletes* is emended to include also verrucate trilete megaspores having a tetrad mark that extends to the equatorial outline.

Verrutriletes albertensis Binda and Srivastava, **n. sp.**
Plate 1, figures 12–14

Description: Megaspore trilete, biconvex with the higher convexity on the distal surface; tetrad mark well defined and raised, extending up to the equatorial margin; arms of the tetrad mark 25 microns wide; amb subtriangular with convex sides; proximal and distal surfaces densely verrucate; verrucae 10 to 12 microns wide at the base.

Size: Equatorial diameter 360 microns.

Holotype: Locality 2; Slide No. BS1/31; plate 1, figures 12–14.

Genus HORTISPORITES Potonié, 1956

Hortisporites canadensis Binda and Srivastava, **n. sp.**
Plate 2, figures 4–8

Description: Megaspore trilete, biconvex; proximal surface almost flattened; tetrad mark well defined and raised, extending up to the equatorial margin; arms of the tetrad mark about 35 microns wide; amb subrounded; proximal and distal surfaces reticulate; reticulum coarse; muri 25 to 30 microns wide; lumina 500 to 550 square microns in area.

Size: Equatorial diameter 690 microns.

Holotype: Locality 1; Slide No. BS1/29; plate 2, figures 4–6.

Remarks: H. canadensis differs from *H. reticulifer* (Dijkstra) Potonié, 1956, in having a raised tetrad mark that extends up to the margin and large reticulations with thick, well-defined muri.

Genus ***Stelckisporites*** Binda and Srivastava, **n. gen.**

Type species: Stelckisporites standardensis Binda and Srivastava, n. sp.

Diagnosis: Megaspore trilete, zonate; laesurae wide, extending up to the margin of the zona; well-defined labra on either side of the commissures; amb triangular to subtriangular with convex sides; exine surface heavily ornamented (granulate, verrucate, rugate, striate, reticulate, *etc.*); ornamentation denser on the distal surface.

Remarks: Genus *Stelckisporites* differs from *Triletes* Reinsch, emend. Schopf, 1938, in having a well-defined zona and laesurae with well-developed labra extending up to the margin of the zona. The elements of the ornamentation are always large, while the genus *Triletes* accommodates mostly smooth or slightly ornamented forms.

The generic name is given in honor of Dr. C. R. Stelck, Professor of Geology, University of Alberta, Edmonton.

Stelckisporites standardensis Binda and Srivastava, **n. sp.**
Plate 2, figures 9–11; plate 3, figures 1–2

Description: Megaspore trilete, biconvex with higher convexity on distal surface; zonate; zona about 40 to

50 microns wide; laesurae 25 microns wide, extending up to the margin of the zona; labra well developed, about 20 microns thick; amb subtriangular with convex sides; proximal surface sparsely verrucose, its verrucae about 25 microns in diameter, sometimes two or three of them fusing to form rugate structures; distal surface densely verrucose, its verrucae larger than 50 microns in diameter.

Size: Equatorial diameter 590 microns.

Holotype: Locality 1; Slide No. BS1/27; plate 2, figures 9–11.

Remarks: The trivial name is taken from the town of Standard, Alberta.

Stelckisporites tenuistriatus Binda and Srivastava, **n. sp.**
Plate 3, figures 3–6

Description: Megaspore trilete, biconvex with higher convexity on distal surface, zonate; zona transparent, about 40 microns wide; laesurae 20 to 25 microns wide, extending up to the margin of the zona; labra thin; amb subrounded with 3 angular apices; proximal surface ornamented with thin ridges running both parallel and at an angle to the equatorial outline and thus forming a coarse reticulate pattern, and with sparsely distributed knoblike structures about 35 microns wide at the base; distal surface with ridges running at an angle to the equatorial outline and ornamented with sparsely distributed knobs.

Size: Equatorial diameter 580 microns.

Holotype: Locality 1; Slide No. BS1/35; plate 3, figures 3–5.

Stelckisporites verrucosus Binda and Srivastava, **n. sp.**
Plate 3, figures 7–11

Description: Megaspore trilete, biconvex with higher convexity on distal surface, zonate; zona transparent, 50 microns wide; laesurae 25 to 30 microns wide, extending up to the margin of the zona; labra well-developed, about 15 microns thick; amb subtriangular with convex sides; proximal surface verrucose, its verrucae about 50 microns wide at the base; distal surface more densely verrucate with the verrucae larger than on the proximal surface and studded side by side, giving the appearance of a negative reticulate pattern.

Size: Equatorial diameter 620 microns.

Holotype: Locality 1; Slide No. BS2/27; plate 3, figures 7–9.

Genus ***Selenasporites*** Binda and Srivastava, **n. gen.**

Diagnosis: Megaspore without tetrad mark or lete, globular to oval in shape; ornamentation reticulate.

Remarks: The name of the genus is derived from the Greek word *selene* (moon). The megaspore has the general shape of the full moon.

Selenasporites reticulatus Binda and Srivastava, **n. sp.**
Plate 3, figure 12

Description: Megaspore without tetrad mark, biconvex; amb circular to ovate; ornamentation reticulate; muri about 15 microns wide; lumina up to 400 square microns in area.

Size: Equatorial diameter 430 microns.

Holotype: Locality 4; Slide No. BS2/35; plate 3, figure 12.

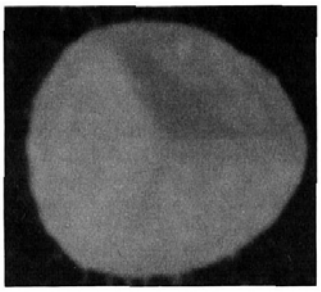
PLATE 1

All figures ×100, unless otherwise indicated

1–6 *Henrisporites granulatus* Binda and Srivastava, n. sp.
1–3, holotype; 1, proximal view; 2, distal view; 3, lateral view; 4, section parallel to polar axis, ×117; 5–6, details of spore wall, ×440.

7–11 *Henrisporites elkwaterensis* Binda and Srivastava, n. sp.
7–9, holotype; 7, proximal view; 8, distal view; 9; lateral view; 10, section parallel to polar axis, ×117; 11, details of the spore wall, ×440.

12–14 *Verrutriletes albertensis* Binda and Srivastava, n. sp.
Holotype; 12, proximal view; 13, distal view; 14, lateral view.



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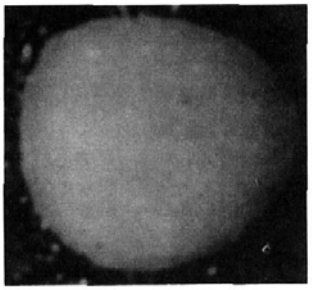

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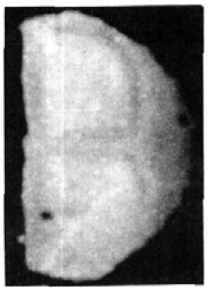

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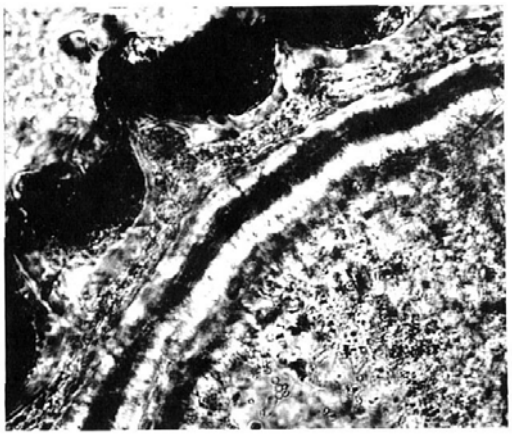

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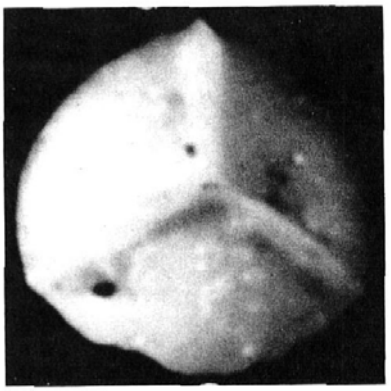

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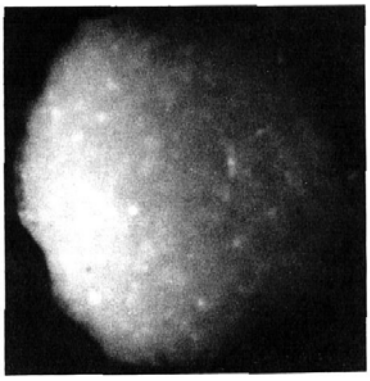

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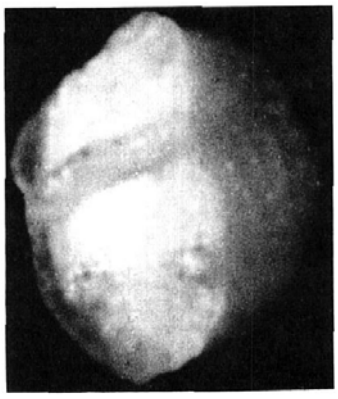

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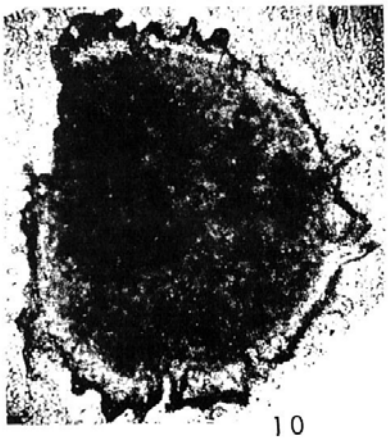

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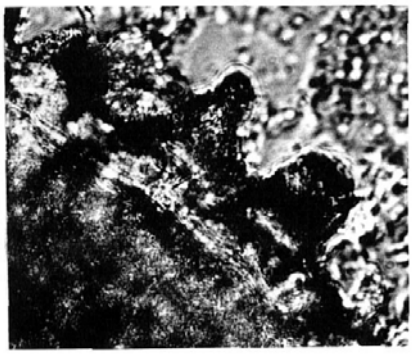

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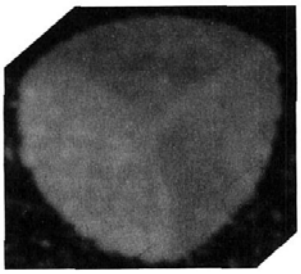

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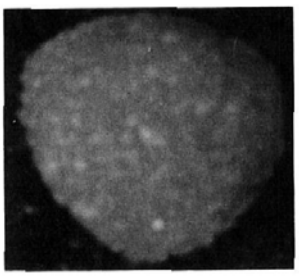

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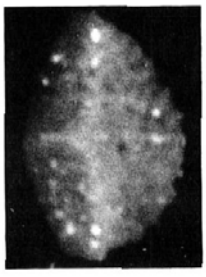

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DISCUSSION

The finding of the silicified megaspores in a shale brings up the problem of the chemistry of the transformation from the original organic matter of the spore to silica. Although the authors do not intend to give here a detailed study of the subject, it seems safe to assume that a fine replacement of the organic matter has taken place. From the thin sections of plates 1–3, it is evident that we are not dealing with casts. The preservation of the finest features of the spore walls seems to clearly point towards a metasomatic replacement in the silica-rich diagenetic environment of the bentonites. There is a possibility that fossils of this type may have been missed quite often by other workers, due to the practice of macerating the shales in hydrofluoric acid in order to recover organic remains of various palynomorphs.

The specimens described in this paper have been referred to form genera, but one may speculate upon their analogies and affinities with specimens of extant genera. Similar megaspores have been related by various workers to those of the order Lycopodiales. The zonate forms may have an affinity with the megaspores of the family Selaginellaceae. The morphological similarity of the reticulate megaspores to those of the extant genus *Isoetes* is striking. *Isoetes* species have slightly ornamented to reticulate megaspores. The genus *Isoetes* is diverse in habitat, its species ranging from lacustrine forms submerged in five or more feet of water to xerophytic ones, but keeping their structural characters usually constant (Pfeiffer, 1922). Extant forms of the genus *Isoetes* are only known from the fresh-water habitat. These fossil silicified megaspores also suggest a fresh-water environment. Their evidence is supported by considerable geological evidence and by the character of the microfloral assemblages recovered from the same formation (Srivastava, 1966, 1967).

The stratigraphic value and importance of silicified megaspores is not yet clear, but, as the work progresses, and more and more specimens are found in various localities, it seems possible that they might be used successfully as a correlation tool in the Upper Cretaceous of southern Alberta.

ACKNOWLEDGMENTS

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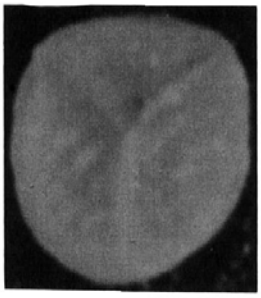
PLATE 2

All figures ×100, unless otherwise indicated

1–3 *Henrisporites sheilae* Binda and Srivastava, n. sp.
Holotype; 1, proximal view; 2, distal view; 3, lateral view.

4–8 *Horstisporites canadensis* Binda and Srivastava, n. sp.
4–6, holotype; 4, proximal view; 5, distal view; 6, lateral view; 7, section parallel to polar axis, ×117; 8, details of the spore wall, ×440.

9–11 *Stelckisporites standardensis* Binda and Srivastava, n. sp.
Holotype; 9, proximal view; 10, distal view; 11, lateral view.



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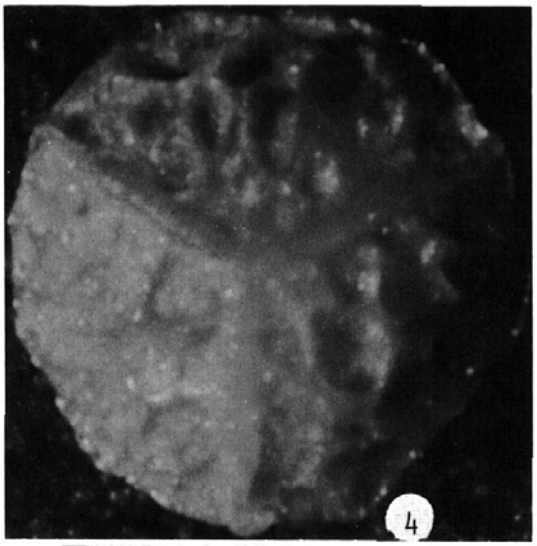

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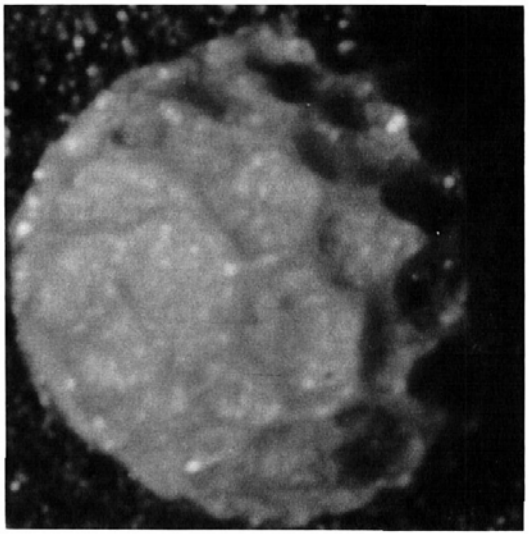

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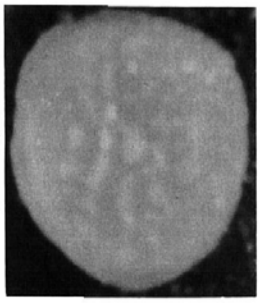

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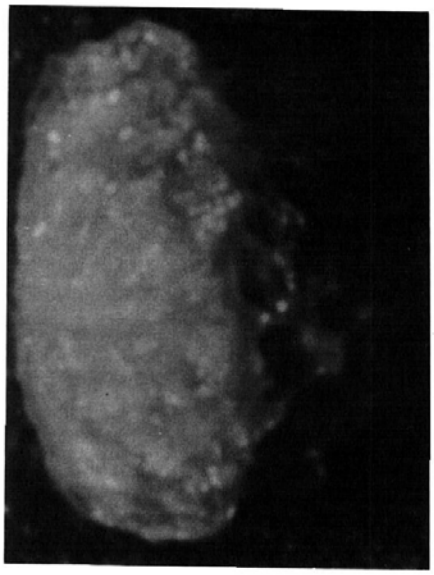

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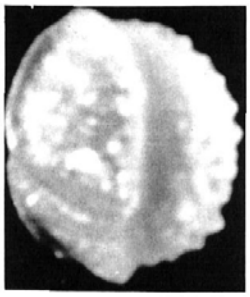

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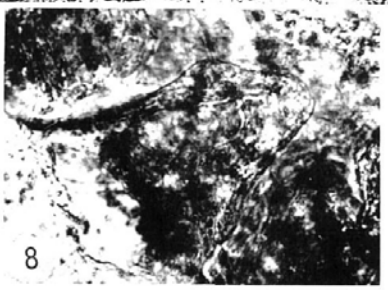

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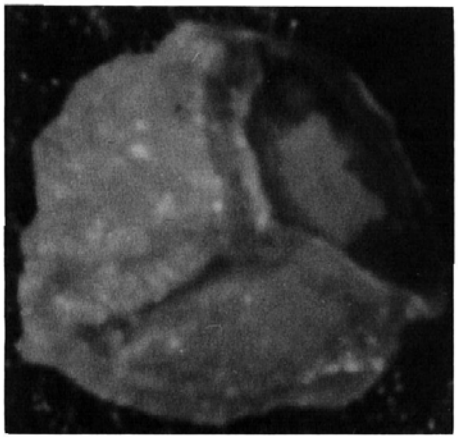

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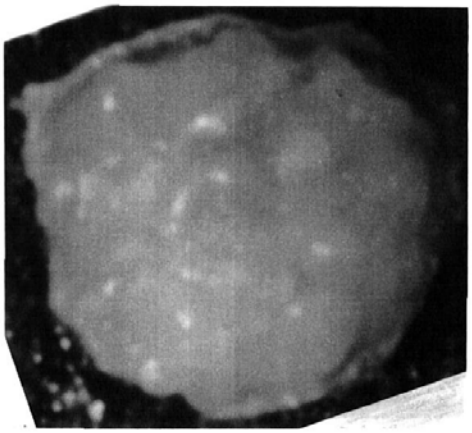

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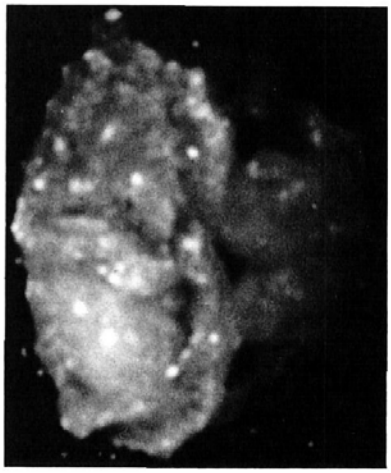

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PLATE 3

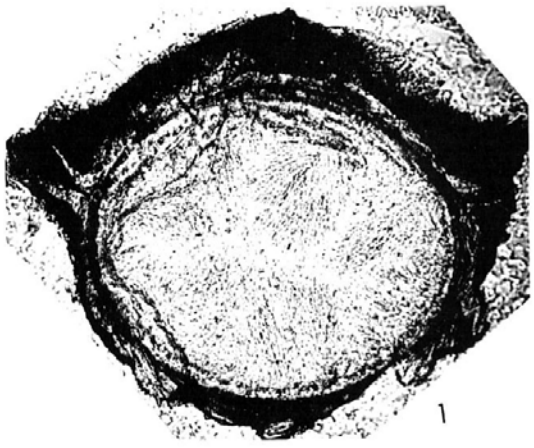
All figures ×100, unless otherwise indicated

1–2 *Stelckisporites standardensis* Binda and Srivastava, n. sp.
1, section parallel to polar axis, ×117; 2, details of the spore wall, ×440.

3–6 *Stelckisporites tenuistriatus* Binda and Srivastava, n. sp.
3–5, holotype; 3, proximal view; 4, distal view; 5, lateral view; 6, section parallel to polar axis, ×117.

7–11 *Stelckisporites verrucosus* Binda and Srivastava, n. sp.
7–9, holotype; 7, proximal view; 8, distal view; 9, lateral view; 10, section parallel to polar axis, ×117; 11, details of the spore wall, ×440.

12 *Selenasporites reticulatus* Binda and Srivastava, n. sp.
Holotype.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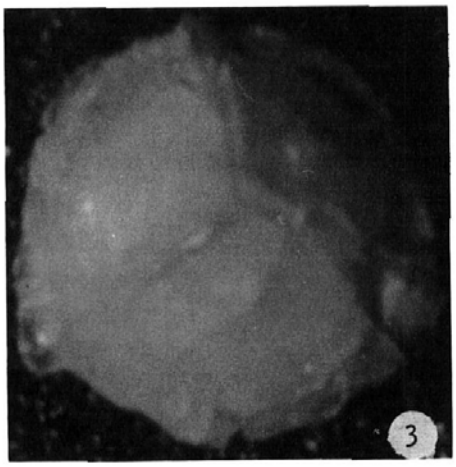
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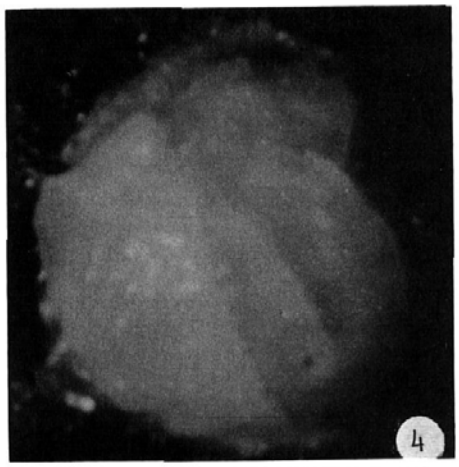
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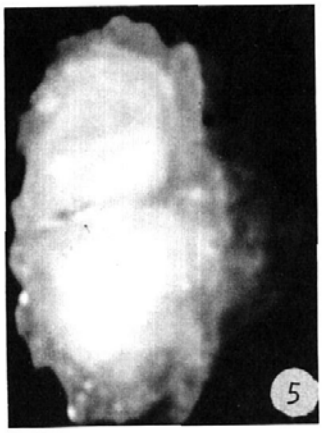
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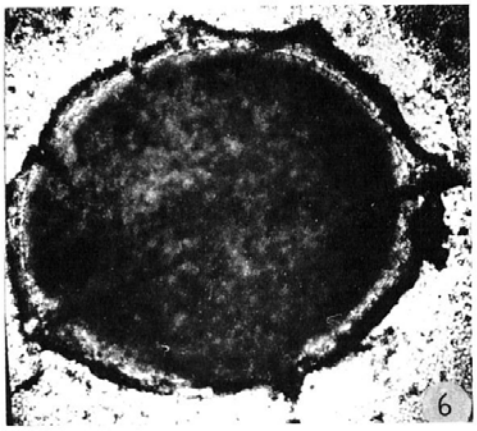
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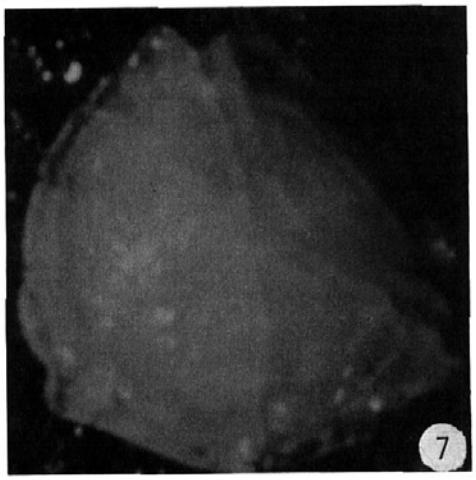
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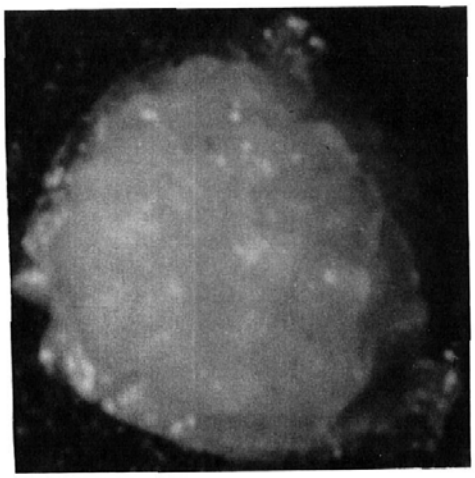
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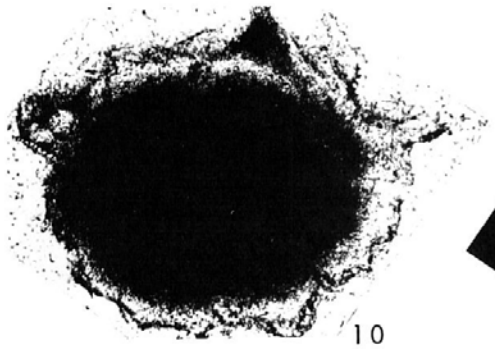
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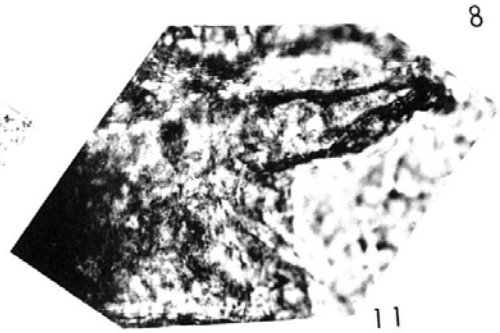
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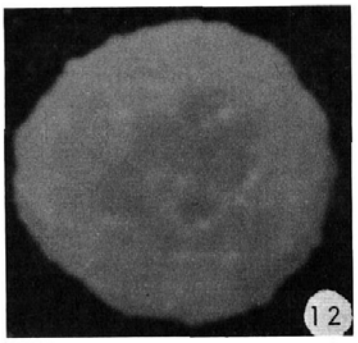
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