Reports

Precambrian Fossils (?) near Elliot Lake, Ontario

Abstract. *Complex structures in Upper Huronian (Lower Proterozoic) quartzite north of Lake Huron are interpreted as probable metazoan fossils aged between 2 and 2.5 $\times$ 10^9 years. They are preserved as sand casts in the form of curved spindles having inclined lateral corrugations, axial marking, and apparent bilateral symmetry.*

The possibility of advanced forms of life during the Precambrian has long been discussed. Our knowledge of the then-distribution of the main groups of fossils has been reviewed (*1*). While megafossils and trace fossils are known from the later part of the Proterozoic, evidence of the presence of such forms in older rocks has not been widely accepted. In this regard one is faced with two main problems: (i) to establish that a particular structure is biogenic, and (ii) to establish its age. The first problem has perhaps been the more difficult; some of the forms in question are sinuous or polygonal sand casts that can be reasonably explained as either shrinkage-crack fillings or fossils.

Remarkably well-preserved structures (see cover) (*2*) were recently discovered in the classic Huronian rocks, of Early Proterozoic age. I consider these to be of biologic origin, but they could be inorganic. They support previous interpretations of similar structures from the Huronian (*3, 4*) as biogenic, and may establish that complex forms of life existed at least 2 billion years ago—about three times the age of remains previously accepted as metazoans.

The specimens are from near the east end of Flack Lake, Township 157, Ontario, about 23.3 km north-northwest of Elliot Lake (46°35′10″N, 82°44′20″W). The original slab came from loose blocks blasted from the northeast side of the first cut on road 639, north of the creek connecting Jimchrist (Christman) Lake with Flack Lake (Figs. 1 and 2); additional specimens come from both sides of the cut. Similar structures occur in the cuts to the southeast, and in the creek bed between the road and Flack Lake.

The Flack Lake area is underlaid by slightly folded and faulted Huronian rocks of the Cobalt Group, which dip gently to the south (*5*). They occupy an easterly trending basin, 45 km long by 15 km wide, having structural discordance along the southern margin. The Huronian sediments, which may be older than 2155 ± 80 million years (*6*), rest unconformably on an Archaean granitic basement, about 2500 million years old, and are cut by basic intrusives. The pre-Huronian unconformity forms the present northern boundary of the basin.

The Cobalt Group in the area comprises four units: The basal Gowganda Formation, consisting of boulder conglomerates probably less than 100 m thick but thickening to the south, is interpreted as a glacial deposit. It is overlaid by the Lorrain Formation, a series of feldspathic quartzites, red and white quartzites, and white-quartz-pebble conglomerates that is between 650 and 1450 m thick. The Lorrain is succeeded by the Gordon Lake Formation ("Banded Cherty Quartzite") and the Bar River Formation ("Upper White Quartzite") (*5, 7*); each is estimated to be several hundred meters thick. The specimens are from near the middle of the Bar River Formation, the youngest Huronian unit in the area. The rocks are quartz arenites, mainly white, but with colors ranging from light green to pink; cross-bedding and ripple marks abound, and thin green and red argillaceous layers are intercalated.

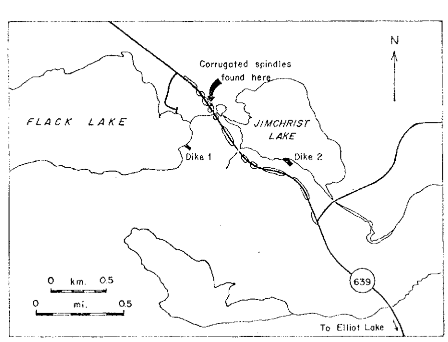


Fig. 1. Source of the specimens: road cuts in Bar River Formation ("Upper White Quartzite"), and dated diabase dikes. Minimum ages: dike 1, 1390 ± 120 million years; dike 2, 1340 ± 120 million years.

Two northwest-trending basic dikes cut this formation close to the source of the specimens; one, 450 m to the southwest; the other, 800 m to the southeast (Fig. 1). Potassium:argon whole-rock determinations (*8*) on the dikes gave minimum ages of 1390 ± 120 and 1340 ± 120 million years, respectively. The age of the large Nipissing diabase body intruding the Gordon Lake Formation, 6.4 km northwest of the sources of the sample (Fig. 2), has been determined at 2130 ± 215 million years, by the Rb:Sr method, from a whole-rock sample of the diabase (*6*, sample 34). The structures that I interpret as fossils are thus older than 1390 million years, probably older than 2130 million years, but younger than 2500 million years.

The best-preserved structures (Figs. 3 and 4) occur along the upper surface of a quartzite slab measuring approximately 8 by 17 by 7 to 9 cm high. The block is ripple-marked and cross-bedded; the ripple marks, the surface expression of the cross-bedding seen in side view, have a wavelength of 8 cm and a height of 8 mm. The grain size decreases from about 0.5 mm at the bottom to 0.1 and 0.2 mm at the top of the slab. The structures are curved cylindrical rods of lithified sand, with tapering ends; they are partly covered by a surface sculpture of regularly spaced, inclined, crescentic corrugations along the sides, 1 to 3 mm apart. The sand is of the same grain size as the matrix, but is slightly lighter in color in some spindles because of lesser amounts of iron oxide cement. A distinct longitudinal median band or marking occupies approximately half the width of the bodies and rises above the corrugations in two specimens. The lateral corrugations may be either symmetrically paired or alternate; some seem to be paired (Fig. 3, specimen 2), but most of the others appear to alternate. The notches are inclined at angles of from 35° to 45°

from the axis, as seen from above; in side view they are crescentic.

All the corrugated specimens of the slab (Fig. 3, specimens 1–6) are incomplete, but they are up to 0.9 cm across and the largest is at least 12.4 cm long (Table 1). Four distinct regions can be differentiated along their axes; (i) the thickest portion, which is uncorrugated; (ii) an adjoining well-corrugated and noticeably tapering portion, followed by (iii) a region of nearly constant width; and (iv) a thicker terminal portion, with a bluntly pointed end. A peculiar pattern of interconnection exists between the specimens: the pointed ends (Fig. 3, specimens 2–5) appear to bud from, overlie, or penetrate other specimens almost at right angles.

The spindles occupy the troughs of the ripple marks, with their apical termini pointing in the upcurrent direction, as determined by cross-bedding seen in vertical section. Where visible in cross section (Fig. 3, specimens 1, 2, 5, 6) they are circular to elliptical, have distinct boundaries, and lie half-buried directly in the sandstone matrix without any intervening pelitic layer. Small patches of light-olive-gray pelitic material are attached to the lateral parts of the spindles. A shallow marginal depression on the bedding surface surrounds the spindles. Thin sections made from three spindles from two other slabs show horizontal alignment of elongated quartz grains.

Specimen 1 (Fig. 3) is the largest and best-preserved of all, but incomplete at both ends; it differs from all others in having two regions of lateral corrugations in which the inclinations of the notches are opposed. The acute angles outlined by the notches point toward the central portion. Longitudinally the corrugations are not noticeably differentiated in size, but their spacing is slightly closer on the concave than on the convex side of the spindle; they appear to alternate.

Specimen 2 is next-best preserved; it also shows the slightly closer spacing of corrugations on the concave side. Corrugations appear to be symmetrically paired; they are lacking at the thickest portion, but weakly indented ones appear on the sides of the thin portion that has constant width.

Specimen 3 has notches that are poorly developed, but large near the thick end; they are smallest at the thinner portion. The smooth pointed and thickened end abuts against specimen 2 and may penetrate it below the surface; the junction is chipped and the relation is unclear.

Corrugations on specimen 4 become more closely spaced toward the thinner, apical end, which penetrates specimen 3 for at least 3 mm. Specimen 5 is a short, pointed fragment, with well-developed corrugations converging away from the apex that connects with specimen 1 and possibly penetrates it. Specimen 6 is a poorly preserved short fragment with comparatively small corrugations that are best seen in side view. Specimen 7 is a nondescript fragment with a median band but lacking corrugations. Specimen 8 is an indistinct rod lacking apparent corrugations and median band. Specimens 7 and 8 are of doubtful affinity.

In addition to the spindles lying parallel to bedding, there are seven irregularly elliptical, protruding patches

Table 1. Statistical summary of specimens of *Rhysonetron lahtii* n. gen., n. sp. Specimens 7 and 8 are of doubtful affinity.

Specimen			Notches				
No.	Min. length (mm)	Max. width (mm)	On side (No.) Convex	On side (No.) Concave	Apparent pattern	Spacing (mm)	Median band
1	124	7.1	22	20	Alternating	2.0–2.5	Present
2	87	9.0	20	30	Symmetrical	1.3–1.9	Present
3	97	8.0	5	11		1.0–2.2	Present
4	63	6.2	17	25	Alternating?	1.0–2.1	Present?
5	31	6.5	7	6	Alternating?	1.8–2.0	Present
6	35	6.8	5	11	Alternating?	1.5	Present
7	15	5.0	0	0			Present
8	48	5.0	0	0			
9	55	5.0	3	0		2.0	
10	21	2.8	7	8	Alternating	2.0–2.5	
11	32	3.5	11	6	Symmetrical?	2.2	
12	47	4.0	7	13	Symmetrical?	2.8–3.0	Present
13	35	6.5	5	0		2.1–2.3	Present?
14	52	4.5	8	3		1.2–1.5	
15	61	5.0	5	0		2.0	Present
16	32	3.5	4	0		2.0	
17	31	7.0	4	9	Symmetrical?	1.5	Present?
18	98	5.0	11	7	Alternating	1.8–2.2	Present
19	67	3.5	6	6	Alternating	3.0	
20	48	5.5	5	6	Symmetrical?	2.0–2.2	Present
21	36	6.0	6	6	Alternating	3.0–4.0	

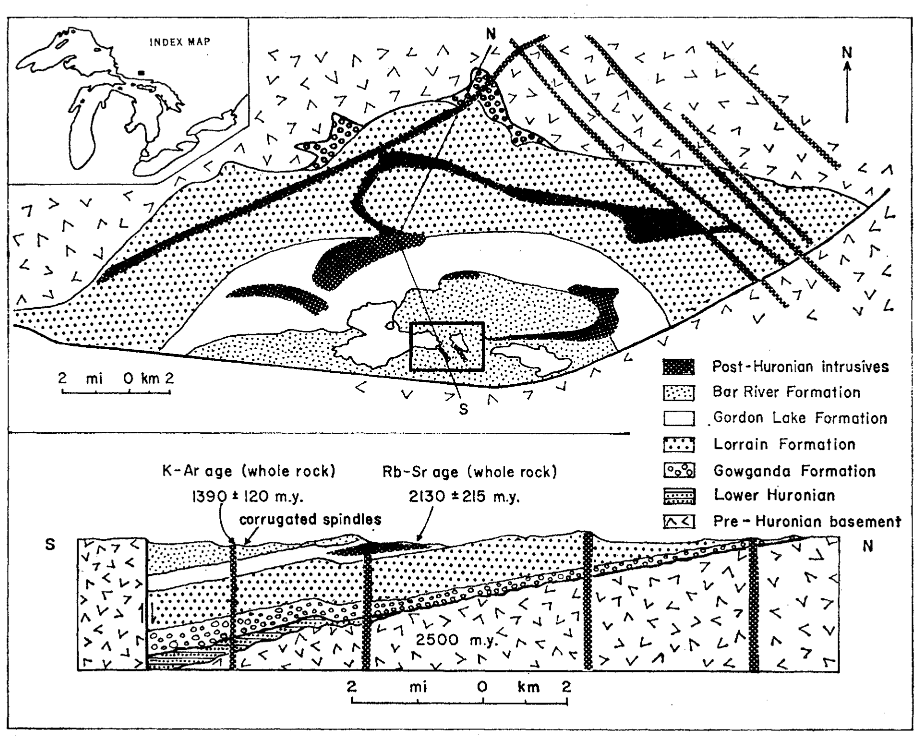


Fig. 2. The Flack Lake area (*5*), and a north–south section showing interpretation of structural relations. Rectangle delineates area covered by Fig. 1.

(Fig. 3, *A–G*); they too are confined to the ripple troughs. The structures and ripples are slightly truncated by erosion.

Other corrugated spindles from the area of the find are less impressively developed than the original specimens; there is great profusion of uncorrugated rods along bedding planes, not necessarily rippled, throughout at least 6 m of section within the Bar River Formation.

Structures similar in gross pattern to those just described occur widely in many geologic systems, being variously regarded as organic (burrows, algae, sponges, gut casts, redeposited and filled worm tubes) or inorganic (mud-crack fillings). Several possible interpretations can be considered. So far, proponents of the inorganic explanation have been the more eloquent (*9–12*), but arguments for a biologic origin of some Huronian spindles similar to those from Flack Lake are substantial (*3, 4*). The evidence, however, of an algal origin (*13*) for similar structures from Asia is inconclusive; it seems likely that such forms are polygenetic, and that one single explanation cannot apply to all the similar-looking forms. I regard the Flack Lake specimens as of organic origin for the following reasons:

1) The specimens fall within a certain size range; they duplicate a complex morphology of tapering cylindrical shape, longitudinal differentiation like that of modern annelids such as *Arenicola*, medial marking, uniform and inclined corrugations, and apparent bilateral symmetry. Collectively, these features indicate a biologic phenomenon.

2) The structures are discrete bodies; they are composed of sand and are embedded in sand of the same grain size, but are clearly separable from the matrix; they overlie others or penetrate them with their pointed ends; there is very little or no pelitic material at the bottom of the spindles. These factors seem to rule out the mud-crack interpretation. (The light-olive-gray shale attached to the lateral portions of the specimens may be a post-spindleform accumulation laid down in the ripple troughs and on top of the spindles; but it may have been squeezed from below the spindles during compaction.)

3) The alternating or symmetrically paired corrugations resemble the patterns of several biogenic structures (trace fossils) that record the impressions of locomotive appendages of various invertebrates—for example, *Scolicia* de Quatrefages 1849 (*14*).

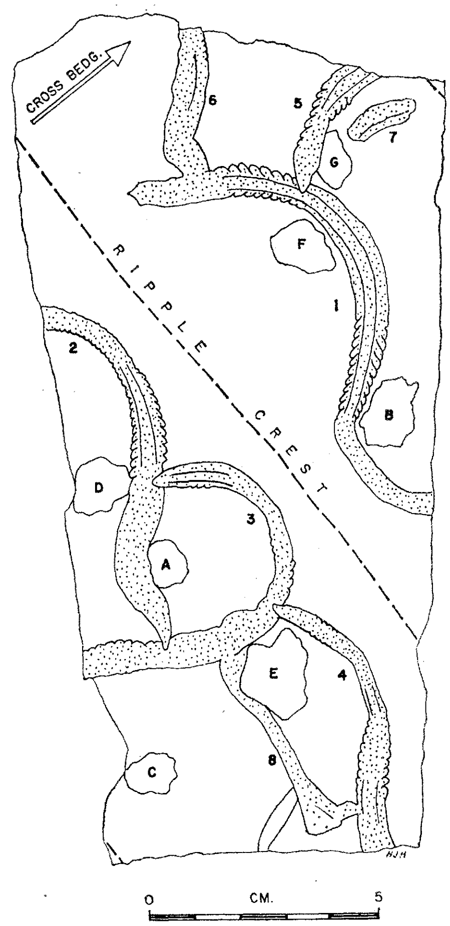


Fig. 3. Identification of specimens (Fig. 4): corrugated spindles by numerals, protrusions by letters.

4) The corrugations are spaced slightly farther apart on the convex side than on the concave on at least two spindles; this fact suggests relative extension and compression, respectively, of regularly annulated and flexible bodies. The spacing may also reflect differential motion of "outside" and "inside" appendages during movement entailing translation and change in direction.

Although I interpret these bodies as structures of biologic origin, any attempt to assign them to a more definite taxonomic position must now be highly speculative in view of their great age. Yet one may speculate: annelids, trace fossils, sponges, and, perhaps, coelenterates or something completely new are possibilities.

Ginsburg (*4*) has suggested that the structures from the Lorrain Formation at Desbarats, Ontario (Figs. 7 and 8), may be casts of some sort of parchment tubes, possibly of worms or worm-like organisms; the Flack Lake structures may be similar in origin. Such parchment tubes are produced by annelids like *Chaetopterus* in modern near-shore environments (*15*). The tubes vary in shape from very open U-shapes to figures of eight (*16*); they may have been eroded by increased wave activity or during storms, redeposited, and filled with sand from the surroundings. If such excavated tubes become deposited in pools above the shoreline, one can expect their common association with mud cracks that form in material deposited as post-accumulation fines. The association would make it more difficult to recognize and identify the bodies that are of biologic origin. The irregularly elliptical protrusions (Fig. 3, *A–G*) may be truncated buried spindles.

Curious is the opposed direction of inclination of the corrugations in specimen 1; it may result from movement, in opposite directions, by an organism that reversed itself inside the tube; or it may be connected with the shriveling of a dehydrating gelatinous capsule or body.

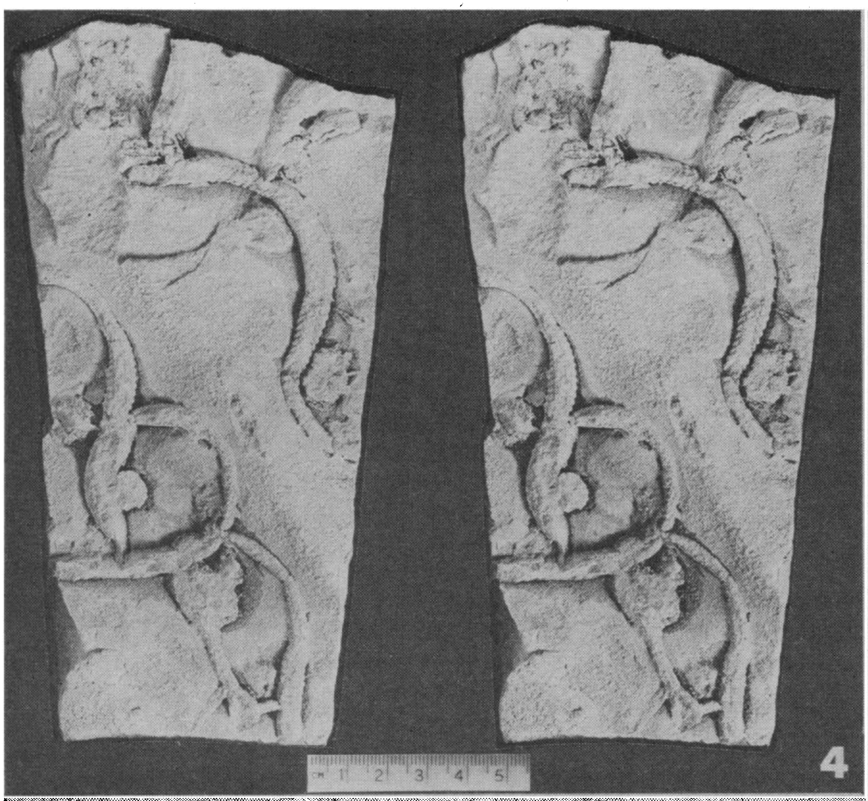
An argument against a parchment-tube origin is that such structures have not yet been found in an upright position. On the other hand, the tubes may have been built horizontally in the sand, or even as agglutinated tubes on the sand.

The structures are unlikely to be gut casts because of their variable thickness and the nature of the points of contact. However, uncorrugated rods seen in certain slabs, as well as some unbranched corrugated ones, may be burrow casts of the *Palaeophycus* type.

The bodies may be casts or molds of the organisms themselves, reflecting a pattern of growth by budding or branching. In morphology and branching pattern one may compare the spindles with some Devonian and Mississippian siliceous sponges (Titusvilliidae; *17*). Even reversal of the inclination of the corrugations (specimen 1) is represented by a somewhat different type of reversal of cups in *Titusvillia.* But the Huronian spindles lack the completeness of the cup-like nodes, a central tubular cavity, and a reticulated surface—possibly because of different preservation.

Factors contesting a biologic origin may be the resemblance to, and intimate association of the structures with, polygonal networks of uncorrugated rods (Fig. 6) probably produced by shrinkage, injection, or crystal-growth mechanisms. In the outcrops along the east shore of Flack Lake these networks occur in ripple troughs, and their size appears to be directly related to the size of the ripple marks.

For the corrugated rods in the road cuts, however, no size relation to ripple marks is established; although they are more abundant in ripple troughs, some do cross, and are imbedded in, the ripple crests without much change in size. While it is conceivable, because of their resemblance and association, that the corrugated rods and the polygonal networks both result from some inorganic mechanism, it is also possible—even likely—that the structures represent two or three different phenomena, one of which may be biologic. The organic interpretation should not be ruled out solely because of presumed absence or scarcity of metazoan remains in the greater part of the Proterozoic succession. Similarly, the inorganic interpretation cannot be completely ruled out just because a



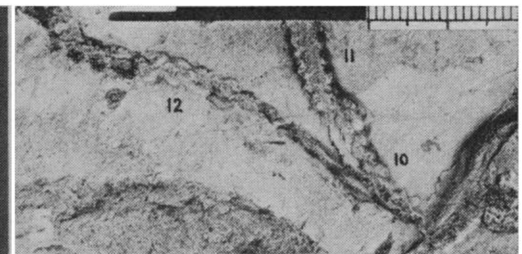


Fig. 4. Stereophoto pair of holotype slab (upper surface) of *Rhysonetron lahtii* n. gen., n. sp. (Geol. Surv. Can. holotype 9876; × 0.5). Fig. 5. *Rhysonetron lahtii* n. gen., n. sp. Specimen 10, with alternating corrugations, and specimens 11 and 12, with nearly symmetrical corrugations (Geol. Surv. Can. paratype 22626; × 1). Fig. 6. Polygonal network of uncorrugated rods associated with corrugated spindles (arrow); rods probably inorganic (× 0.18). Fig. 7. Corrugated and overlapping spindles (lower right) from near Desbarats, Ontario; lower surface of *Rhysonetron byei* n. gen., n. sp. (Geol. Surv. Can. holotype 15,379; × 1). Fig. 8. Overlapping spindles from near Desbarats, Ontario. Upper-surface view of *Rhysonetron byei* n. gen., n. sp.; specimen at center has faint corrugations (Geol. Surv. Can. paratype 22,628; × 1).

close modern inorganic analogue with corrugations has not yet been found.

Inasmuch as I favor the biologic interpretation of the corrugated structures, I propose a formal taxonomic designation for reference purposes:

Rhysonetron, new genus

Diagnosis: Discrete long, curved, cylindrical, and tapering rods or spindles of fine-to-medium-grained arenaceous material, embedded in similar material; varying in cross section from circular to elliptical, and having longitudinal median marking or sculpture and oblique, lateral, crescentic corrugations; pointed ends may be free or may connect with or overlap other specimens. Length, at least five times greater than width.

Etymology: *rhysos* (Gr.), wrinkled; *netron* (Gr.), spindle

Type species: *Rhysonetron lahtii*, new species (Figs. 4 and 5)

Specific characteristics: Spindles longitudinally differentiated, and marked with well-developed alternating or symmetrically paired corrugations spaced 1 to 3 mm apart.

Etymology: Named in honor of the discoverer, Victor Lahti of Elliot Lake.

Type occurrence: Bar River Formation (Fig. 2; *7*)

Type material: Geol. Surv. Can. holotype No. 9876; paratypes No. 22626, 22627

Rhysonetron byei, new species (Figs. 7 and 8; Frarey and McLaren, 1963, Fig. 1)

Specific characteristics: Spindles smaller, more slender, and less well differentiated longitudinally than *R. lahtii*; faint corrugations spaced 0.8 to 1.0 mm apart.

Etymology: Named in honor of the discoverer, C. E. Bye of Sault Sainte Marie, Ontario.

Type occurrence: Crestal area of outcrops of red sandstone in woods 2.6 km northeast of main intersection in Desbarats, Ontario (46°21′40″N, 83°53′55″W). Lorrain Formation

Type material: Geological Survey of Canada holotype No. 15379; paratype No. 22628

Implications. The corrugated structures from Flack Lake are at present the most convincing evidence of the existence of advanced organisms during the Early Proterozoic. Although it is possible that they may be explained as of inorganic origin, it seems unlikely that forms of such complexity could entirely result from some inorganic process. The complex organization favors a biologic interpretation.

If they are in fact biogenic, the implications of this discovery are profound: they may establish the presence of metazoans more than 2000 million years ago, extending the range of our knowledge to at least three times the previously generally accepted age of the oldest metazoan remains. The implications would include problems relating to the definition of the base of the Paleozoic (*18*), and to theories of the geochemical evolution of the oceans and the atmosphere, especially with regard to the appearance of oxygen. Furthermore, they would emphasize that well-sorted arenaceous sediments are a suitable environment for the preservation of Precambrian biogenic structures, and are favorable prospecting grounds for Precambrian fossils.

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References and Notes

1. M. F. Glaessner, *Biol. Rev. Cambridge Phil. Soc.* **37**, 467 (1962); *Earth-Sci. Rev.* **1**, 29 (1966).
2. The structures described were discovered in May 1966 by V. Lahti of Elliot Lake; they reached the Geological Survey of Canada through F. R. Joubin in July 1966. I have visited the locality and confirmed the find. The additional specimens that I collected are less-well preserved.
3. H. Faul, *Nature* **164**, 32 (1949); *J. Paleontol.* **24**, 102 (1950).
4. M. J. Frarey and D. J. McLaren, *Nature* **200**, 461 (1963); M. J. Frarey, R. N. Ginsburg, D. J. McLaren, in program Geol. Soc. Amer. 1963 Ann. Meeting, p. 63A.
5. W. D. Harding, in *Ontario Dept. Mines Ann. Rept. 48* (1941), pt. 11, pp. 1–12; P. E. Giblin and E. J. Leahy, Compilers, *Ontario Dept. Mines Prelim. Geol. Map P. 304* (1965); W. H. Collins, in *Geol. Surv. Can. Mem. 143* (1925), pp. 1–160.
6. C. H. Stockwell, in *Geol. Surv. Can. Paper 64–17* (1964), pt. 2, fig. 1; R. Van Schmus, *J. Geol.* **73**, 755 (1965); Rb:Sr ages are based on decay constant $\lambda Rb^{87} = 1.39 \times 10^{-11}$/year.
7. M. J. Frarey, *Geol. Surv. Can. Paper 67–6*, in press.
8. By R. K. Wanless, Geological Survey of Canada. Potassium:argon age calculations are based on the following K^{40} decay constants: $\lambda_e = 0.585 \times 10^{-10}$/year; $\lambda_{total} = 5.30 \times 10^{-10}$/year.
9. W. Häntzschel, *Mitt. Geol. Staatsinst. Hamburg* **19**, 77 (1949).
10. H. E. Wheeler and J. J. Quinlan, *J. Sediment. Petrol.* **21**, 141 (1951); S. W. Hobbs, A. B. Griggs, R. E. Wallace, A. B. Campbell, *U.S. Geol. Surv. Profess Paper 478* (1965), p. 20.
11. O. H. Schindewolf, in *Geotektonisches Symposium zu Ehren von Hans Stille*, F. Lotze, Ed. (Enke, Stuttgart, 1956), p. 455.
12. W. C. Barnes and A. G. Smith, *Nature* **201**, 1018 (1964).
13. R. Endo, *Japan. J. Geol. Geograph.* **11**, 43 (1933); H. Yabe, *ibid.* **16**, 205 (1939); V. P. Maslov, *Akad. Nauk SSSR Trans. Inst. Geol. Nauk* **85** ser. 24, 1 (1947).
14. W. Häntzschel, in *Treatise on Invertebrate Paleontology*, R. C. Moore, Ed. (Geol. Soc. Amer. and Univ. of Kansas Press, 1962), p. W 177.
15. H. E. Enders, *J. Morphol.* **20**, 479 (1909); A. Seilacher, *Neues Jahrb. Geol. Palaeontol.* **96**, 428 (1953).
16. J. Joyeux-Laffuie, *Arch. Zool. Exp.* **8**, 245 (1890).
17. J. M. Clarke, *N.Y. State Museum Bull.* **196**, 177 (1918); **219-220**, 143 (1920); K. E. Caster, *J. Paleontol.* **13**, 1 (1939); *ibid.* p. 531; in *Paleontograph. Amer.* **2**(12) (1941).
18. C. A. Nelson and P. E. Cloud, *Science* **154**, 766 (1966).
19. I thank Mr. and Mrs. V. Lahti for cooperation, permission to publish, and specimens; M. J. Frarey, B. S. Norford, and D. J. McLaren for critical reading of the manuscript; K. E. Caster, P. E. Cloud, R. N. Ginsburg, F. J. Pettijohn, S. M. Roscoe, and J. W. Schopf for criticism, suggestion, and discussion; and K. Hatai, Tohoku University, Sendai, Japan, for rubber molds and photographs of the types of *Manchuriophycus yamamotoi* and *M. inexpectans* compared with *Rhysonetron*.

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Mössbauer Analysis of Iron in Clay Minerals

Abstract. *Mössbauer absorption spectrography can be used to establish the presence of Fe^{2+} and Fe^{3+} in clay minerals. In the sheet structure silicates, octahedrally coordinated iron can be distinguished from tetrahedrally coordinated iron. Siderite and goethite, common contaminants of the clay minerals, can usually be detected. Goethite has a well-organized structure, though, owing to its fine grain size, it may appear to be amorphous to x-rays. The various families of clay minerals show minor differences in isomer shift and quadrupole splitting values, caused by variations in the character of the octahedral layer.*

Most of the clay minerals contain iron in their lattice and often they may contain an admixture or coating of iron oxides. It is difficult and often impossible to determine whether the iron associated with clays is in the lattice or is external. Even if this can be established, there is no means of knowing where the iron occurs in the lattice (tetrahedral or octahedral coordination). It is also usual for most clays to have iron present in both the Fe^{2+} and Fe^{3+} state. In addition, the clay minerals have three different structural arrangements—2 : 1 sheet, 1 : 1 sheet, and chain. The sheet structure types have dioctahedral (two of the three octahedral positions filled) and trioctahedral members. Thus, the octahedral iron occurs in a wide variety of environments. Further, chlorite contains two octahedral layers. In one layer the iron is coordinated largely by oxygen ions, and in the other (brucite layer), by hydroxyl ions (*1*).

We obtained Mössbauer spectra of Fe^{57} in a number of clay minerals and micas to determine the feasibility of using this technique to learn more about the character and location of the iron in clay minerals. A number of studies (*2, 3*) have indicated that the various silicate families have relatively distinct spectra, but there appears to