ecliptic plane, and the seasons on Uranus average 21 terrestrial years in length. During 1966, the axis of Uranus was practically in the plane normal to the solar radius vector, all parts of the planet "seeing" the sun during one rotational period. In 1985, the north pole of Uranus will face the sun continuously.
9. J. L. Elliot, E. Dunham, L. H. Wasserman, R. L. Millis, J. Churms, *Astron. J.* **83**, 980 (1978).
10. The assumption of an adiabatic lapse rate in the atmosphere is open to question since Uranus may not have an internal heat source [L. Trafton, *Rev. Geophys. Space Phys.* **19** (No. 1), 43 (1981)].
11. L. Wallace, *Icarus* **43**, 231 (1980).
12. J. F. Appleby, thesis, State University of New York at Stony Brook (1980).
13. S. J. Weidenschilling and J. S. Lewis, *Icarus* **20**, 465 (1973).
14. This research was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

27 December 1982; revised 18 April 1983

Ediacaran (Precambrian) Fossils from the Wernecke Mountains, Northwestern Canada

Abstract. *Fossil medusoids identified as* Cyclomedusa davidi?, Beltanelliformis brunsae, *and cf.* Sekwia excentrica *are reported from Late Precambrian strata in the Wernecke Mountains. They are representatives of the Ediacaran fauna, the oldest assemblage of cosmopolitan metazoans, and are only the third such occurrence in Canada. In addition, specimens broadly resembling the problematic structure* Rugoinfractus ovruchensis, *previously known only from the Precambrian of the Ukraine, are reported from the Lower Cambrian of the nearby Mackenzie Mountains.*

The term "Ediacaran fauna" refers to a Late Precambrian assemblage of fossils of soft-bodied animals, mainly coelenterates and annelids, first discovered in the Ediacara Hills of South Australia. This fauna represents the earliest abundant record of metazoan life and underlies what is presently the oldest Paleozoic system, the Cambrian, which is characterized by the development of animals with hard parts. Sparse but nevertheless worldwide finds of the Ediacaran fauna have prompted a call for an Ediacaran (or Ediacarian) Period and System (*1–3*). While a decision on this proposal must await judgment by the geological community, there is a current need to demonstrate the fauna's geographic and stratigraphic distribution and its limits in terms of evolution. We report here a favorable new region in which to search for Ediacaran fossils and describe and illustrate some specimens collected in July 1982.

The geographic location and stratigraphic position of the fossils are shown in Fig. 1. Section 1, located in the Wernecke Mountains, Yukon Territory, represents the local stratigraphy at and near three of the fossil localities. Composite sections 2 and 3 in the nearby Mackenzie Mountains, Northwest Territories, represent a fourth locality as well as other previously reported fossil localities (*4, 5*) that are relevant to this discussion. The approximate location of the Precambrian-Cambrian boundary in the two sections is based on current work by W.H.F. and G.M.N. on trace fossil ranges.

Evidence for a small late Precambrian faunal assemblage in the Mackenzie Mountains was reported by Fritz (*4*) and later confirmed by Hofmann (*5*). The biota includes the coelenterates *Inkrylovia* Fedonkin and *Sekwia* Hofmann, the trace fossils *Gordia* Emmons and *Torrowangea* Webby, and problematic remains. We now confirm the presence of additional representatives of the Ediacaran fauna in the post-tillite, Late Precambrian sequence of the the Wernecke Mountains. These comprise the medusoids *Cyclomedusa davidi?* Sprigg, *Beltanelliformis brunsae* Menner, and cf. *Sekwia excentrica* Hofmann. We also recovered remains from the lower Cambrian in the Mackenzie Mountains that broadly resemble *Rugoinfractus ovruchensis* Paliy, reported from the Middle Riphean of the Ukraine; these were considered by Paliy (*6*) and Durham (*7*) to be undoubted trace fossils and by Cloud and Glaessner (*2*) to be shrinkage crack fillings.

Fossils referred to *C. davidi?* Sprigg (Fig. 2, A and B) comprise centimetric, circular to subcircular medusoid impressions on a bedding plane of a light brown weathering, greenish-gray, fine-grained, argillaceous sandstone belonging to an unnamed formation. The 15 specimens in Fig. 2A distinct enough to be measured are disks 1.7 to 7.0 cm in diameter (mean, 4.0 cm) characterized by moderately developed concentric rugae and a distinct central depression several millimeters across with a relief 1 to 3 mm higher than that of the rugate portion. The largest specimen (Fig. 2B) has delicate, uniformly spaced, radial striae in an inner annular zone between the central depression and the outer rugae; its outer margin is broadly indented on one side, and on the opposite side it is deformed because of the superposition and impression of another specimen that is slightly smaller and much more poorly preserved. These features indicate that the disks are the impressions of independent, cohesive, organized pliable bodies and rule out a nonbiological origin for them. The size, circular outline, concentric rugae, central structure, and radial striae of our fossils correspond to the characteristics of *Cyclomedusa* Sprigg. The forms are closest to *C. davidi* Sprigg, although the rugae are not as coarse as in some typical Australian specimens. We therefore tentatively assign our fossils to Sprigg's species.

Beltanelliformis brunsae Menner (Fig. 2C), also interpreted as medusoid impressions, is represented by centimetric round protuberances on the surface of bedding planes of medium-grained, cross-laminated sandstone in contact with dark gray mudstone. The protuberances are 1 to 2 cm across and 1 to 3 mm high and exhibit delicate peripheral and transverse wrinkles. The central portion of individuals is flat to very gently undulating, whereas the margin is moderately to steeply sloped, giving the structures the appearance of short, truncated cones. The forms most closely resemble the structures illustrated by Fedonkin (*8*) from the Valdai Series (Vendian) of the Onega Peninsula on the White Sea.

A single specimen of a third type of structure (Fig. 2D) resembles the fossil medusoid *S. excentrica* Hofmann, which is found slightly lower in the stratigraphic sequence in section 2 (*5*). It is a subcircular depression, about 2.2 cm across and 1 mm deep, from a brownish-gray weathering, medium-grained, micaceous sandstone. The specimen has faint eccentric markings and an indistinct annular depression at the margin. Since the preservation is poor and only one specimen is available, our identification is incomplete.

Lastly, under cf. *R. ovruchensis* Paliy, we record remains of rounded, oblong structures with apparent bilateral symmetry and tripartite organization (Fig. 2E) occurring in greenish-gray to purple, medium-grained, micaceous sandstone at section 2. The structures are found in a succession containing abundant trace fossils and are stratigraphically above levels with *Protohertzina* cf. *P. anabarica* Missarzhevskiy (*9*) and *Phycodes pedum* Rud. Richter (*4*) and 340 m below the top of the *Fallotaspis* Zone. They are thus probably of Early Cambrian age. The forms are preserved as sand fillings

on bedding surfaces and are 3.5 to 7.5 cm long, 1.7 to 2.0 cm wide, and 1 to 3 mm high. The termini are bluntly rounded; an axial ridge about 2 mm wide and 0.5 mm high, flanked by a barely perceptible groove on either side, runs the entire length of the body and separates two lateral lobes. Under certain conditions of diffuse lighting there is a suggestion of delicate submillimetric transverse markings on some portions of the lateral lobes. The lateral lobes are gently convex in transverse section, with the greatest steepness at the outer margin. Structures of similar size and shape, but slightly deeper, are described under *R. ovruchensis* Paliy from the Tovkach Formation (Ovruch Series) of the Ukraine (*6*), said to be of Middle Riphean age, and considered to be burrows by the author of the taxon. *Rugoinfractus* was compared with *Didymaulichnus* Young by Durham (*7*), but Cloud and Glaessner (*2*) interpreted the structures as mud crack fillings. Although we regard our specimens as biogenic—and the trace fossil interpretation is possible—the

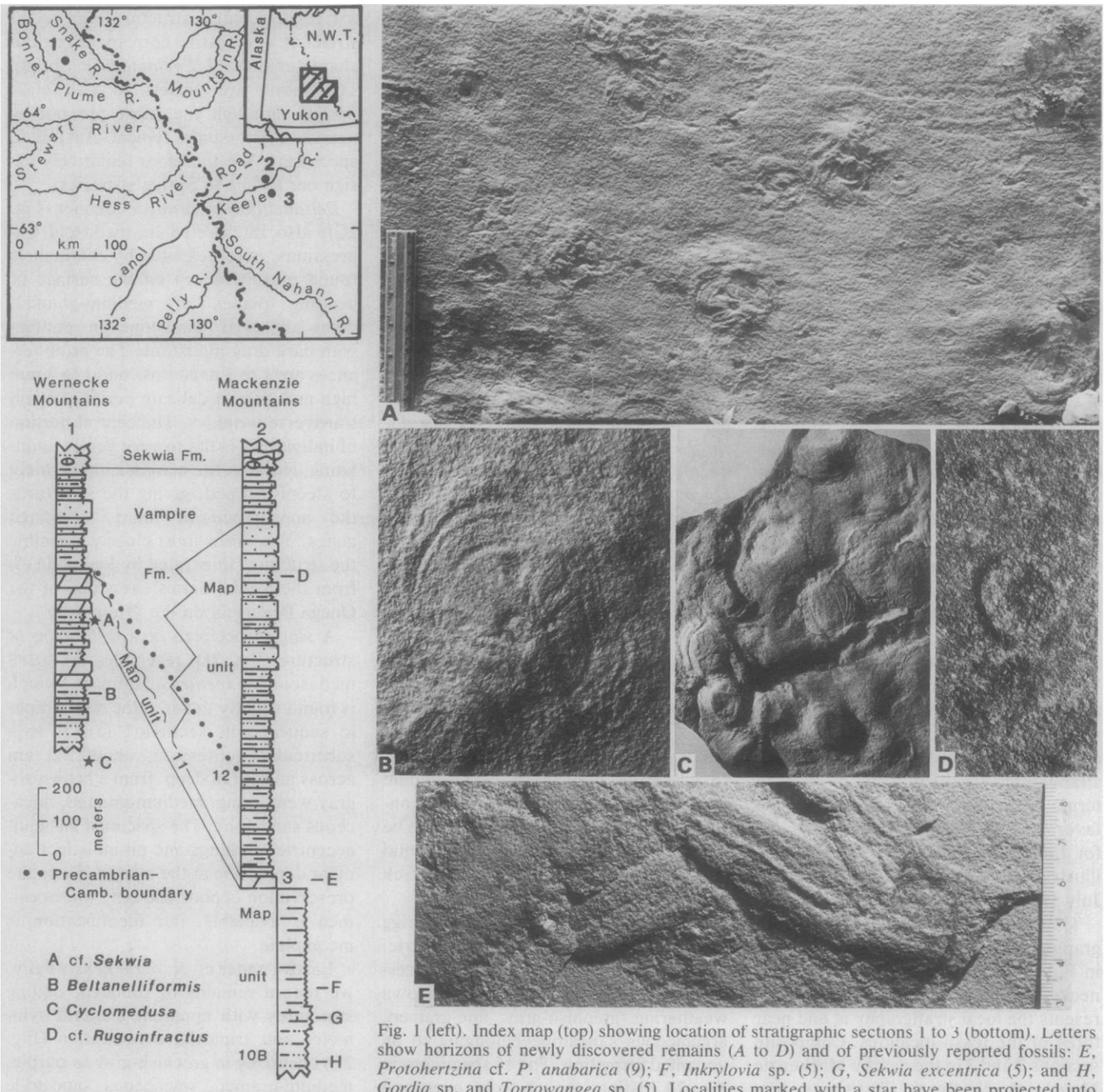

Fig. 1 (left). Index map (top) showing location of stratigraphic sections 1 to 3 (bottom). Letters show horizons of newly discovered remains (*A* to *D*) and of previously reported fossils: *E*, *Protohertzina* cf. *P. anabarica* (*9*); *F*, *Inkrylovia* sp. (*5*); *G*, *Sekwia excentrica* (*5*); and *H*, *Gordia* sp. and *Torrowangea* sp. (*5*). Localities marked with a star have been projected into section. Position of the Precambrian-Cambrian boundry is approximate. Fig. 2 (right). Ediacaran fossils (A to D) and Early Cambrian fossil (E) from the Yukon and Northwest Territories. Scale in (E) also applies to (B) through (D). (A) *Cyclomedusa davidi?*; field photo of bedding surface showing medusoid impressions. Specimen just below center of photo is hypotype GSC 73051; specimen at bottom right is hypotype GSC 73052. Locality is a large loose block from an unnamed formation (GSC field locality 99093; 64°26′50″N, 132°27′00″W) just above water level on the southeast side of Goz Creek, corresponding to horizon C in stratigraphic section 1, which is located 25.8 km to the west-northwest. (B) *Cyclomedusa davidi?*; enlarged view of GSC 73051. (C) *Beltanelliformis brunsae*; hypotype GSC 73053, from a loose block at horizon B, 22.5 m below unnamed dolostone in section 1 (GSC field locality 99095; 64°32′15″N, 132°56′45″W). (D) cf. *Sekwia excentrica*; hypotype GSC 73054, from a loose block at horizon A, 26.5 m below map unit 11 (GSC field locality 99047; 64°38′40″N, 132°54′00″W), 12.0 km north of section 1. (E) Specimens broadly resembling *Rugoinfractus ovruchensis*; hypotype GSC 73055, from a loose block at horizon D, 161 m below top of map unit 12, section 2 (GSC field locality 99151; 63°29′20″N, 128°40′30″W). Specimens assigned GSC numbers are part of the National Type Fossil Collection, Geological Survey of Canada, Ottawa.

shape and the broadly rounded termini are also consistent with an interpretation as body-fossil casts. A wormlike animal with a general organization resembling that of *Marywadea* Glaessner and *Palaeoplatoda* Fedonkin are candidates, but the lack of identifiable anterior-posterior polarity and the absence of strong segmentation preclude closer comparison with these genera. The affinities of our Early Cambrian specimens are thus as yet undetermined.

The new medusoid finds increase the total number of known Late Precambrian metazoan genera in the Canadian Cordillera from two to four. The fauna now comprises the coelenterate taxa *Inkrylovia* sp., *S. excentrica*, *B. brunsae*, and *C. davidi?* and the originators of the trace fossils *Gordia* sp. and *Torrowangea* sp. In addition, several problematic structures have been described.

Correlation of the fossiliferous Late Precambrian beds in northwestern Canada with units containing the Ediacaran fauna in South Australia and the White Sea area is strengthened by the new finds, particularly since they include the most widely distributed Ediacaran medusoid, *Cyclomedusa* (*10*). The data also support the case for the recognition of a formal period based on the Ediacaran fauna (*1, 2*). We expect that continued work in the Canadian Cordillera in general, and in the Wernecke and Mackenzie mountains in particular, will further this concept, although progess may be slower in these remote areas than it would be in more readily accessible regions.

H. J. HOFMANN
Department of Geology, University of Montreal, Montreal, Canada H3C 3J7
W. H. FRITZ
Geological Survey of Canada, Ottawa, Ontario, Canada K1A 0E8
G. M. NARBONNE*
Department of Geology, University of Montreal

References and Notes

1. R. J. F. Jenkins, *Trans. R. Soc. South Aust.* **105**, 179 (1981).
2. P. Cloud and M. F. Glaessner, *Science* **217**, 783 (1982).
3. The spelling is Ediacaran by Jenkins (*1*) and Ediacarian by Cloud and Glaessner (*2*), whose concept of the interval also differs from Jenkins's. The term was introduced by H. Termier and G. Termier [*Rev. Gen. Sci. Pures Appl.* **67**, 79 (1960)] as *Ediacarien* (in French). The French version requires the adjectival *i*, whereas this is not required for the English adjectival form of Ediacara, the place for which the fauna, period, and system are named.
4. W. H. Fritz, *Geol. Surv. Can. Pap. 80-1A* (1980), p. 41.
5. H. J. Hofmann, *Lethaia*, **14**, 303 (1981).
6. V. M. Paliy, *Akad. Nauk Ukr. SSR Dopovidi Ser. B* (1974), p. 34.
7. J. W. Durham, *Annu. Rev. Earth Planet. Sci.* **6**, 37 (1978).
8. M. A. Fedonkin, *Akad. Nauk SSSR Geol. Inst. Trans.* **342**, 58 (1981).
9. S. Conway Morris and W. H. Fritz, *Nature (London)* **286**, 381 (1980).
10. *Cyclomedusa* is now known from North America as well as from Europe, Asia, Australia, and Africa [M. F. Glaessner, in *Treatise on Invertebrate Paleontology*, R. A. Robinson and C. Teichert, Eds. (Geological Society of America, Boulder, Colo., and University of Kansas, Lawrence, 1979), part A, p. 94].
11. This work was carried out under research agreement 227/4/82 with the Canadian Department of Energy, Mines and Resources and Geological Survey of Canada project 650024.
* Present address: Department of Geological Sciences, Queen's University, Kingston, Ontario, Canada, K7L 3N6.

12 April 1983

Lessons from the Silica "Decline" in Lake Michigan

Abstract. *A new analysis of data obtained from water treatment plants on Lake Michigan fails to support published contentions, based on such data, that the silica content of the lake has declined during the last five decades. The purported silica decline appears to have been due to changes in analytical methods and laboratories. Had such changes been avoided, an invaluable record of the silica content of the lake could have been obtained.*

In 1967, Powers and Ayers suggested that the silica (SiO_2) content in Lake Michigan had been declining since 1926 (*1*). Schelske and Stoermer (*2*) then hypothesized that this long-term decline in SiO_2 would lead to changes in the composition of the algal flora from diatoms to less desirable blue-green or green algae. They suggested that the SiO_2 decline resulted from the withdrawal of dissolved SiO_2 by diatoms because of increasing rates of phosphorus input to Lake Michigan and subsequent sedimentation of the diatom remains (*2, 3*). Their hypothesis has been repeatedly cited by one or both of the authors until recently, and it has been incorporated into textbooks of limnology (*4*) and a review of SiO_2 dynamics (*5*). It has even played a role in recent litigation between Milwaukee and Illinois (*6*).

The Schelske-Stoermer hypothesis was based on two sets of observations: (i) increasing rates of phosphorus inputs to Lake Michigan and (ii) the data summarized by Powers and Ayers (*1*) showing an apparent decrease in the average annual SiO_2 concentrations in influents to drinking-water treatment plants in Chicago, Milwaukee, and Grand Rapids between 1926 and 1962. There can be little argument with the notion of increasing phosphorus supplies to Lake Michigan. However, our analysis of the data on which the SiO_2 decline suggested by Powers and Ayers was based, and of data gathered since then, provides little support for the Schelske-Stoermer hypothesis.

At first glance, the evidence appears incontrovertible. The change in the SiO_2 content of the lake with time was particularly striking at Chicago (Fig. 1A), and a regression analysis of the 1926–1962 Chicago data yields a highly significant (see Table 1) decline of 0.10 part per million (ppm) of SiO_2 per year; or, as expressed by Schelske and Stoermer, a decrease of "at least 4 mg/liter in the last 44 years" (*2*, p. 423)—about a 60 percent decrease overall. Nonetheless, a more careful analysis reveals that the Chicago data fall into at least two groups, data for the years from 1926 to 1948 with an average SiO_2 concentration of about 3.9 ppm and those from 1949 to 1962 with an average of about 2.0 ppm (Fig. 1B). This drop in SiO_2 is an abrupt one; across the 1948–1949 transition all earlier points are higher than all later points. Slopes computed from the 1926–1948 data yield an average SiO_2 decline of 0.08 ppm per year, in good agreement with the overall 1926–1962 decline of 0.10 ppm per year. However, if the 1926 and 1927 data are not included, the slope is reduced to -0.04 and the regression is not statistically significant. Remarkably, regression analysis of the post-1949 data also reveals no statistically significant overall SiO_2 decline (Table 1).

Two other facts also raise significant questions about the validity of the SiO_2 decline. First, the abrupt change in SiO_2 concentrations is correlated with a change in laboratories performing the analyses (*7*). Second, dissolved SiO_2 was measured through 1948 but total SiO_2 afterward. The latter change should have produced an abrupt increase rather than the observed decrease; this finding suggests that serious analytical error must have occurred, thus invalidating use of the data for establishing long-term trends.

These observations thus contradict the view that the Chicago data document a progressive decline in Lake Michigan's SiO_2 concentration and suggest rather that the 1926–1963 "decline" (*1, 2*) depends solely upon the joining of the two sets of data (1926–1948 and 1949–1962), which have different means (*8*).

What about data from other cities? Powers and Ayers compared Chicago's SiO_2 data with what they assumed were