

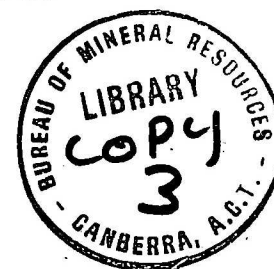
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MEGASCOPIC ALGAE 1300 MILLION YEARS OLD

FROM THE BELT SUPERGROUP, MONTANA: A

REINTERPRETATION OF WALCOTT'S HELMINTHOIDICHNITES

by

M.R. WALTER, JOHN H. OEHLER and DOROTHY Z. OEHLER

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Running Head: Precambrian Megascopic Algae

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MEGASCOPIC ALGAE 1300 MILLION YEARS OLD FROM THE BELT SUPERGROUP,
MONTANA: A REINTERPRETATION OF WALCOTT'S *HELMINTHOIDICHNITES*

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ABSTRACT

In 1899, C.D. Walcott described carbonaceous films on bedding surfaces of dark grey shale from the 1300 m.y. old Greyson Shale of the Belt Supergroup in Montana as trace fossils, assigning them to the genus *Helminthoidichnites* Fitch. We have re-examined Walcott's collection and have concluded that the fossils represent megascopic and probably eukaryotic algae. They are redescribed here under the names *Proterotainia montana*, n. gen., n. sp., *P. neihartensis* (Walcott), *Lanceoforma striata*, n. gen., n. sp., and *Grypania spiralis* (Walcott), n. gen. These are the oldest megascopic body fossils now known, and they extend the known record of megascopic algae by at least 400 m.y. The relatively high diversity and quality of preservation of these fossils demonstrate that fine-grained, clastic sediments are potential repositories of well-preserved Precambrian plants.

INTRODUCTION

The fossil record of Precambrian life consists largely of a documentation of the early history of microorganisms and structures (stromatolites) built by microorganisms. Very little is known of the early evolutionary history of megascopic Precambrian life. Until now, the oldest authenticated megascopic body fossils reported were algal metaphytes (megascopic, multicellular, eukaryotic algae) from the late Precambrian of Norway (Spjeldnaes, 1963) and Russia (Gnilovskaja, 1971) and metazoans from the late Precambrian of Australia and elsewhere (Glaessner and Wade, 1966; Glaessner, 1971). We here report megascopic body fossils, believed to represent eukaryotic algae, from grey shales of the approximately 1300 m.y. old Greyson Shale of the Belt Supergroup of Montana. This report greatly extends the known record of megascopic plant life.

The fossils studied were collected by C.D. Walcott who interpreted them as metazoan trails, assigning them to the trace fossil genus *Helminthoidichnites* Fitch (Walcott, 1899). They were regarded subsequently by Cloud (1968, p.55) as "probably algal". Results of our investigation support Cloud's conclusion and suggest further that the organisms represented were probably eukaryotic algae related to the Phaeophyta, Rhodophyta, or Chlorophyta. The great difference in age between these fossils and all megascopic algae known from younger Precambrian sediments

highlights the incompleteness of the late Precambrian fossil record as presently known. This occurrence also draws attention to fissile clastic sediments as potential repositories of well-preserved Precambrian plants.

Most megafossils from the Belt Supergroup that were originally regarded as metazoans have been reinterpreted as either algal remains or sedimentary structures. For example, the "brachiopod" *Lingulella montana* (Fenton and Fenton, 1936) is now regarded as a stromatolite (Cloud, 1968). Specimens of the "burrow" *Planolites* (Walcott, 1899) were inspected recently (by M.R.W.) and are considered to be isolated ripple marks and concretions. At least some specimens of the "arthropod" *Beltina danai* Walcott from the Greyson Shale probably are algal remains (White, 1929; Fenton and Fenton, 1931; Raymond, 1935). Thus, the fossils here described, together with some specimens of *Beltina* and possibly certain organic and ferruginous microstructures (Walcott, 1914; Pflug, 1965a,b, 1966, 1968; Gutstadt and Schopf, 1969; Schopf *et al.*, 1974; White, 1974), appear to constitute the only body fossils now known from sediments of the Belt Supergroup.

METHODS AND ANALYTICAL RESULTS

Samples were immersed in ethanol and were photographed with an Aristophot camera using Polaroid PN55 film. Petrographic thin sections and acid-resistant macerations of the shale were examined by optical microscopy in search of microfossils. No assured microfossils were found. Three fossiliferous shale samples

were coated with gold and examined with a JEOL JSM-2 scanning electron microscope; owing to minimal surface relief, little information was gained by this technique. An electron microprobe was used to determine the distribution of C, S, Ca, Mn and Fe in the fossils and associated minute crystals. The fossils and dark grey patches (e.g. Pl. 1, figs. 1-4) on the bedding planes are carbonaceous but are free of Ca and Mn. The crystals are rich in Fe and, in some cases, in S; they are interpreted as pyrite and goethite after pyrite. A previous investigator apparently has taken peels from the specimens; to avoid further damage to the samples, this treatment was not repeated.

AGE OF THE GREYSON SHALE

Walcott's collections are from two localities in southern Montana: 1) "near the mouth of Deep Creek Canyon, a short distance above Glenwood Post Office"; and 2) "Sawmill Canyon, about four miles above Neihart". The stratigraphic position of these fossils is "in the Greyson shales, in a belt of calcareous shales about 100 feet above the Newland limestone" (Walcott, 1899, p. 235).

The Greyson Shale is a basal unit of the Ravalli Group, in the lower part of the Belt Supergroup (Harrison, 1972). Harrison (1972) has reviewed isotopic data on the age of the Belt Supergroup and has concluded that the Ravalli Group is

1300 m.y. old and that metamorphic rocks underlying the Belt are about 1700 m.y. old. Volcanics in the Windermere Group, unconformably overlying the Belt Supergroup, are probably between 825 and 900 m.y. old (Miller *et al.*, 1973). A Rb-Sr whole-rock isochron for argillaceous rocks within the Greyson Shale and other units low in the Belt indicates an age of 1325 ± 15 m.y. (Obradovich and Peterman, 1968).

Stromatolites have been identified from the Siyeh Limestone and the Missoula Group (above the Greyson Shale) and from the Altyn Limestone (below the Shale). *Conophyton cylindricum* Maslov has been described from the Siyeh Limestone and Missoula Group (Cloud and Semikhatov, 1969); in the USSR this stromatolite occurs in the Middle Riphean ($1350 \pm 50 - 950 \pm 50$ m.y.) and may extend into the Upper Riphean ($950 \pm 50 - 680 \pm 20$ m.y.). *Baicalia* Maslov, also typical of the Middle and Upper Riphean, occurs in the Altyn Limestone (White, 1970). This suggests a maximum age of about 1350 m.y. for the Greyson Shale. Thus the stromatolite and isotopic data are consistent and indicate that the Greyson Shale was deposited about 1300 m.y. ago.

It is highly unlikely that Walcott's specimens could have come from sediments younger than the Greyson Shale for the following reasons: 1) younger sediments similar in lithology to the Greyson Shale are not present at the Deep Creek Canyon locality (according to published maps); 2) although Middle Cambrian sediments occur in the Sawmill Canyon area, Walcott's specimens

from the two localities are in identical rock types; 3) Walcott found no Cambrian fossils in these outcrops; and 4) Walcott gives a precise stratigraphic interval within the Greyson Shale as the provenance of his collections.

DESCRIPTION OF THE FOSSILS

In 24 samples of Walcott's material from the Greyson Shale, 26 fragmentary fossils were recognized. Six of these were illustrated originally by Walcott (1899) as figures 1-2 and 4-7 of his Plate 24. The fossils are dark grey, extremely low relief impressions and carbonaceous films on bedding surfaces of finely laminated, grey shale. Small dark patches of carbonaceous material, similar to that comprising the fossils, are scattered over the bedding planes and are concentrated on and near the fossils. Distributed throughout the shale are small (3 to 6 μm wide) crystals of pyrite and goethite pseudomorphs after pyrite; they occur singly, in clusters (up to 150 μm wide), and in rows (up to 5 mm long). The crystals tend to be concentrated in heavily carbonaceous areas.

On the basis of size and shape the fossils have been grouped into six categories:

- 1) long, narrow, intertwined, unbranched ribbons
(*Helminthoidichnites? neihartensis*, Walcott, 1899, Pl. 24, fig. 2), here named *Proterotainia montana*;

- 2) broad, unbranched ribbons (*H. ? neihartensis*, *op.cit.*, Pl. 24, figs. 1, 4), here named *Proterotainia neihartensis*;
- 3) lanceolate structures, here named *Lanceoforma striata*;
- 4) coiled structures (*H. ? spiralis*, *op.cit.*, Pl. 24, figs. 5, 6), here named *Grypania spiralis*;
- 5) curved ribbons, larger and with more distinct margins than the structures in category 4 (*H. meeki*, *op.cit.*, Pl. 24, fig. 7), here emended to *Helminthoidichnites? meeki*;
- 6) a branched filament, unnamed.

SYSTEMATIC DESCRIPTIONS

"ALGAE"

Division PHAEOPHYTA (?)

or RHODOPHYTA (?)

or CHLOROPHYTA (?)

Class PHAEOPHYCEAE (?)

or RHODOPHYCEAE (?)

or CHLOROPHYCEAE (?)

Genus PROTEROTAINIA Walter, Oehler & Oehler, n. gen.

Diagnosis.— Unbranched, more or less straight (may be folded), ribbon-like carbonaceous films on bedding planes; 0.1 to 2.0 mm in width;

may exceed 125 mm in length; may exhibit longitudinal fibrillar structure.

Type species.- *Proterotainia montana* Walter, Oehler & Oehler, n. sp.

Etymology.- From the Greek *proteros*, earlier and *tainia*, ribbon.

PROTEROTAINIA MONTANA Walter, Oehler & Oehler, n. sp.

Pl. 1, fig. 1a,b

Helminthoidichnites? neihartensis Walcott 1899 partim

Diagnosis.- *Proterotainia* with ribbons approximately 0.13 mm wide, with no clear longitudinal fibrillar structure.

Description.- There is a single pair of unbranched, gently curved and intertwined ribbons 0.13 mm in width (Pl. 1, fig. 1a). One ribbon of the pair is broken forming a twisted loop (Pl. 1, fig. 1b). At the opposite end of the specimen, the ribbons curve back on themselves and are highly folded.

Holotype.- The pair of ribbons shown in Pl. 1, fig. 1 (USNM 210911).

Etymology.- With reference to the provenance from southern Montana.

Type locality.- It is not known from which of the two localities described above this specimen was collected.

Discussion.- We have removed this species from its doubtful assignment to the genus *Helminthoidichnites* because the type species of that genus, *H. tenuis* Fitch 1850, is considered to be a trace fossil, whereas *P. montana* is a body fossil.

PROTEROTAINIA NEIHARTENSIS (Walcott) emend. Walter, Oehler & Oehler

Pl. 1, figs. 2-4; Pl. 2, fig. 1

Helminthoidichnites? neihartensis Walcott 1899 partim

Diagnosis.- *Proterotainia* with ribbons 0.6 to 2.0 mm wide, commonly exhibiting a longitudinal fibrillar structure.

Description.- There are five relatively straight, unbranched ribbons (Pl. 1, figs. 2-4) and one highly folded ribbon or group of ribbons joined by a pair of ribbons to a smaller mass of similar material (Pl. 2, fig. 1); they range in width from 0.6 to 2.0 mm. All of the straight ribbons terminate at rock specimen edges or have at least one end that is either obscured or appears to be an accidental break in the original organism; they range in length from 14 to 125 mm. The longest ribbon (Pl. 1, fig. 4) is split longitudinally near its middle, and goethite crystals are concentrated on the ribbon surface near this break (Pl. 1, fig. 4b). Several ribbons are composed of longitudinal fibrils that are separated locally (Pl. 1, figs. 2-3). One additional specimen in this category is not illustrated.

Lectotype.- As Walcott (1899) did not select a holotype, the specimen illustrated in Pl. 1, fig. 4 (USNM 210914) is here designated as the lectotype.

Type locality.- Walcott (1899) recorded *H.? neihartensis* from both localities described above.

Discussion.- As for *P. montana*. The specimen illustrated in Pl. 1, Fig. 3 was cut into several pieces during our investigation of this material.

Genus LANCEOFORMA Walter, Oehler & Oehler, n. gen.

Diagnosis.- Lanceolate carbonaceous films on bedding planes;
1-2 mm wide and about 9-10 mm long.

Type species.- *Lanceoforma striata* Walter, Oehler & Oehler, n. sp.

Etymology.- From the Latin *lancea*, a light spear and *forma*, shape.

LANCEOFORMA STRIATA Walter, Oehler & Oehler, n. sp.

Pl. 2, figs. 2 and 3

Diagnosis.- As for the genus.

Description.- There are two clearly defined lanceolate fossils (Pl. 2, figs. 2-3), as well as several other, possibly comparable structures, in the vicinity of the fossil shown in Pl. 2, fig. 3 (these are not figured). The better preserved of the two illustrated fossils (Pl. 2, fig. 2) is 9.3 mm long with a maximum width of 2.0 mm; the other specimen (Pl. 2, fig. 3) is 9.0 mm long with a maximum width of 1.0 mm. These fossils seem to represent thin, sheet-like structures folded over on themselves. They taper slightly toward each end, and the better preserved specimen has fine, longitudinal striations on its surface; similar striations are present on the less well-preserved specimen, but are less clearly visible.

Holotype.- The specimen illustrated in Pl. 2, fig. 2 (USNM 210908).

Etymology.- With reference to the surface striations.

Type locality.- It is not known from which of the two localities described above these fossils were collected.

"ALGAE" (?)

Division PHAEOPHYTA (?)

or RHODOPHYTA (?)

or CHLOROPHYTA (?)

Genus GRYPANIA Walter, Oehler & Oehler, n. gen.

Diagnosis.- Unbranched, ribbon-like, carbonaceous films in the form of coils or fragments of coils on bedding planes; ribbons up to 1.0 mm wide.

Type species.- *Grypania spiralis* (Walcott) emend. Walter, Oehler & Oehler.

Etymology.- From the Greek *grypanios*, bowed by age.

GRYPANIA SPIRALIS (Walcott) emend. Walter, Oehler & Oehler

Pl. 2, figs. 4-10

Helminthoidichnites? spiralis Walcott 1899

Diagnosis.- As for the genus.

Description.- There are 11 coiled or curved ribbons (Pl. 2, figs. 4-10), 13 to 44 mm in length and 0.25 to 0.75 mm in width; the coils range from 5.7 to 14.0 mm in maximum diameter. Two of the specimens are tightly coiled at one end and open at the other (Pl. 2, figs. 4-5). Three of the specimens are C-shaped (Pl. 2, figs. 6-7), and one of these appears to consist of a central strand within a sheath-like investment (Pl. 2, fig. 7). Four of

the remaining fossils in this group are loosely coiled spirals (Pl. 2, figs. 8-9), and the last is a tightly coiled spiral (Pl. 2, Fig. 10). One additional C-shaped specimen is not illustrated. All of the fossils are unbranched. Some of the specimens exhibit a faint, regular segmentation along a portion of their lengths (e.g., Pl. 2, figs. 4, 6, 7).

Lectotype.— As Walcott (1899) did not select a holotype, the large coil on the left of Pl. 2, fig. 8 (USNM 210904) is here designated as the lectotype.

Type locality.— The Deep Creek Canyon locality described above.

Discussion.— As for *P. montana*.

The fossils designated as the holotype of *Helminthoidichnites meeki* (or *H. meekii*) by Walcott (1899) are shown in Pl. 2, fig. 12 (USNM 33793). They comprise a single group of curved ribbons (from the Deep Creek Canyon locality) which differ from the other fossils in this collection in that they are sharply delineated, relatively deeply impressed in the rock, and untextured. None of the ribbons is complete, but the largest is 55 mm long by 1.7 to 2.0 mm wide and the next largest is about 30 mm long by 1.5 mm wide. *H. meeki* is known from only one small fragment of Greyson Shale.

Walcott described these fossils as a metazoan trail, but we regard them as probably algal body fossils because where two ribbons overlap (indicated by arrow in Pl. 2, fig. 12), the carbonaceous material of both ribbons is visible. Nevertheless,

these particular structures seem sufficiently similar to Fitch's (1850) description of the putative trace fossil *H. tenuis* (the type species of *Helminthoidichnites*) that transference of Walcott's *H. meeki* to a new genus is not yet justified. Instead, we suggest that for the present these fossils be designated *Helminthoidichnites meeki*.

In addition to the named fossils, there is a single branched filament 19 mm long and 0.08 to 0.09 mm wide (Pl. 2, fig. 11). This specimen consists of a main filament with two slightly narrower, lateral branches that appear to attach to inflection points in the main filament. This structure is not named because it is not certainly a fossil nor is it clearly distinguishable from other fragmentary filamentous structures on the same bedding plane.

All specimens are deposited in the U.S. National Museum, Washington. Specimen numbers are given in the figure captions.

BIOGENICITY OF THE FOSSILS AND SYNGENICITY WITH PRECAMBRIAN SEDIMENTATION

There are several reasons for interpreting these structures as biogenic: 1) all are composed, at least partially, of dark carbonaceous films; 2) most contain concentrations of pyrite or goethite pseudomorphs after pyrite - the pyrite presumably formed as a result of the decomposition of organic matter; 3) the coils and ribbons are essentially uniform in width along their

lengths, a type of uniformity suggestive of biological organization; 4) many of the structures originally were flexible, as is indicated by their folded form (e.g., Pl. 1, fig. 1; Pl. 2, fig. 2); and 5) they resemble fossil organisms but not such potential pseudofossils as desiccation cracks, mud chips or concretions; nor do they resemble dendrites in either form or manganiferous composition.

The fossils must have been deposited synchronously with the shale because the broken and folded ribbons (Pl. 1, figs. 1, 4; Pl. 2, fig. 1) and the folded lanceolate structures (Pl. 2, figs. 2, 3) can only have been so deformed before deposition of the overlying sediment. Moreover, there is no indication of pathways along which any of the structures could have entered the sediment after lithification.

INTERPRETATION OF BIOLOGICAL AFFINITIES

We interpret these structures as body fossils rather than trace fossils because the evidence of folding (Pl. 2, fig. 2) and breakage (Pl. 1, figs. 1, 4) indicates that they were discrete bodies during sedimentation. This interpretation is supported by their carbonaceous composition and their very low relief on bedding planes, characteristics typical of compressed body fossils but uncommon in trace fossils.

The megascopic size of the fossils suggests that they were eukaryotic organisms. Some genera of the prokaryotic blue-

green algae, such as *Wolleea* (Nostocaceae), can attain megascopic size through parallel alignment of microscopic trichomes (chains of cells) within a common, tubular sheath. However, aside from *Wolleea*, most megascopic aggregates of blue-green algae generally are irregular in gross form, unlike the Greyson Shale fossils. Although none of the fossils resembles very closely modern cyanophytes of this type, it is perhaps premature to dismiss entirely the possibility that some of the fossils were "megascopic" blue-green algae.

In contrast, the fossils do resemble in size and morphology many eukaryotic, megascopic algae. For example, *Proterotainia montana* and *P. neihartensis* are similar to certain species of *Chorda* and *Scytosiphon* among the Phaeophyta, *Nemalion* among the Rhodophyta, and *Enteromorpha* among the Chlorophyta. *Lanceoforma* can be compared with some species of *Petalonia* among the Phaeophyta and *Rhodymenia* among the Rhodophyta. *Grypania* appears to lack counterparts among the extant megascopic algae. The apparent segmentation in some specimens of *Grypania* resembles that of segmented "worms", but the segmentation is vague and may be a preservational artifact. Moreover, preservation as carbonaceous films is extremely rare for soft-bodied metazoans, but is common for algae and higher plants, suggesting that these fossils most likely represent plant material, perhaps from a type of alga unknown in the modern biota.

Although certain of the fossils are problematic, it seems most reasonable to interpret at least *Proterotainia* and *Lanceoforma* as remnants of megascopic eukaryotic algae, and probably related, therefore, to the brown, red, or green algae.

DISCUSSION AND CONCLUSIONS

Our interpretation that the Belt fossils here described represent eukaryotic organisms is based principally on their regular form and their megascopic size, which generally exceeds the maximum size ranges of the prokaryotic bacteria and blue-green algae. This interpretation is consistent with microfossil evidence which indicates that eukaryotic organisms had become established by at least 1300 m.y. ago (Cloud *et al.*, 1969; Licari and Troxel, 1973), and perhaps as early as 1600 to 1900 m.y. ago (Hofmann and Jackson, 1969; Schopf, 1970, p. 334-335; Edhorn, 1973; Hofmann, 1974). Our interpretation that the fossils represent algae is based on their morphology and mode of preservation. The occurrence of these fossils in sediments dated at 1300 m.y. in age indicates that megascopic, eukaryotic algae arose at least 400 m.y. earlier than was previously supposed.

Referring to *Beltina danai*, another megafossil from the Greyson Shale, Raymond (1945, p. 382) wrote that it "is not at all improbable that they are of algal origin, perhaps remains of brown algae, though nothing definite can be ascertained from their structure". Aside from *Beltina* and the fossils here described,

only four other occurrences of megascopic algae have been described from Precambrian sediments, and all of these are much younger than 1300 m.y.: Spjeldnaes (1963) has described a late Precambrian (younger than 800 to 900 m.y.) possible dasycladacean green alga, *Papillomembrana compta*, from southern Norway; Vologdin (1966) has reported another possible dasycladacean alga from the late Precambrian of the U.S.S.R. (the age of this occurrence is very poorly established); Glaessner (1963) has interpreted latest Precambrian strap-like structures from South-West Africa as possible large algae; and Gnilovskaja (1971) has described the megascopic, possibly brown, algae, *Vendotaenia antiqua* and *Tyrasotaenia podolica*, from the Vendian (680 ± 20 to 570 ± 10 m.y.) of the Russian Platform. Gnilovskaja's fossils are strikingly similar in size, shape, and mode of preservation to *Proterotainia*, and some members of these two assemblages may represent related taxa, a possibility noted also by Gnilovskaja (1971, p. 374).

It has been proposed that plants and animals attained megascopic size between 700 and 900 m.y. ago and that this was "triggered" by the evolution of sexuality in eukaryotic microorganisms (Schopf *et al.*, 1973). The oldest known microorganisms showing evidence of sexual (meiotic) reproduction occur in cherts of the 800-900 m.y. old Bitter Springs Formation (Schopf and Blacic, 1971). However, it is now apparent that some organisms had attained megascopic size by at least 1300 m.y. ago. Even older organisms possibly were "tending toward" megascopic size; a probably algal,

"multicellular" organism with a maximum dimension of 0.25 mm has been described from the 1500-1600 m.y. old McArthur Group of northern Australia by Croxford *et al.* (1973). Thus, regarding the relationship between eukaryotic sexuality and megascopic size, it now seems evident either (1) that sexually reproductive eukaryotes were extant before 1300 m.y. ago, (2) that the advent of eukaryotic sexuality was not a prerequisite for megascopic size, or (3) that the large size of the Greyson Shale fossils represents an early evolutionary experiment among asexual organisms that may not have been repeated on a wide scale among many taxa until some 500 m.y. later.

Over the past decade the search for body fossils older than the Ediacara fauna has been concentrated on microfossiliferous cherts. Results of our study of the Greyson Shale flora suggest that more attention should be given to fissile, fine-grained clastic sediments. Indeed, the quality of preservation of the fossils here described and the wide range of forms in the small collection available strongly suggest that further collecting in the Greyson Shale alone will provide new specimens potentially useful for elucidating the early history of megascopic life.

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Figure descriptions

EXPLANATION OF PLATE 1

Megascopic algal fossils on parting surfaces of dark grey shale from the Greyson Shale. Samples were photographed in reflected light while immersed in ethanol. Line scales represent 3 mm, except where otherwise indicated.

Fig. 1 - *Proterotainia montana*: narrow, smooth, unbranched ribbons, twisted and intertwined, one broken.
1a, overview of fossils; 1b, detail of loop formed by one end of the broken ribbon (USNM 210911).

Figs. 2-4 - *P. neihartensis*: relatively broad, unbranched ribbons with longitudinal, fibrillar substructure. 2, two crossed ribbons (USNM 210912). 3, fibrillar ribbon (USNM 210913); 3a, overview of fossils; 3b, detail of one end; 3c, detail of the other end; 4, large ribbon split longitudinally into two anastomosing strands, one of which is broken (USNM 210914); 4a, overview of the fossil (arrow indicates area of Fig. 4b); 4b, detail showing concentration of geothite pseudomorphs after pyrite (small black dots) on broken end of one strand.

EXPLANATION OF PLATE 2

Megascopic fossils on parting surfaces of dark grey shale from the Greyson Shale. Samples were photographed in reflected light while immersed in ethanol. Line scales represent 3 mm, except where otherwise indicated.

- Fig. 1 - *P. neihartensis*: highly folded ribbon or mass of ribbons (USNM 210907).
- 2 - 3 *Lanceoforma striata*: folded, lanceolate structures, one of which (Fig. 2) shows parallel, longitudinal striations. 2: USNM 210908, 3: USNM 210909.
- 4 - 10 *Grypania spiralis*: Arrows in 4, 6 and 7 indicate "segmented" portion of coils (apparent branching in figs. 4 and 6 is due to overlap of fragments of coils); 7, coil showing dark medial strand and light outer "investment". 8, 9, loosely coiled spirals (apparent bifurcation in Fig. 9 is a photographic artifact); 10, tightly coiled spiral.
- 4: USNM 210900,
- 5: USNM 210901, 6: USNM 210902, 7: USNM 210903,
- 8: USNM 210904, 9: USNM 210905, 10: USNM 210906.
- 11 - Thin, branched filament (USNM 210910).
- 12 - *Helminthoidichnites? meeki*: smooth, curved ribbons with sharp, carbonaceous margins (USNM 33793). The angular marks peripheral and terminal to one of the ribbons were made during preparation by a previous investigator.

