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NEW OCCURRENCES OF  
THE UNUSUAL TRILOBITE *NARAOIA*  
FROM THE CAMBRIAN OF IDAHO AND UTAH<sup>1</sup>

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*Abstract*—Specimens of the unusual trilobite *Naraoia compacta* Walcott are described from the Gibson Jack Formation of possible late Early Cambrian age in Idaho and the Marjum Formation of late Middle Cambrian age in Utah. These occurrences extend the observed geographic and temporal ranges of *Naraoia*, which previously has been recorded from only the Burgess shale of early Middle Cambrian age in British Columbia. These fossils support the notion that the Burgess shale biota is exceptional only in the conditions of its fossilization.

THE MOST completely preserved, diverse Cambrian biota is that of the celebrated Burgess shale of the Stephen Formation in British Columbia, which was discovered in 1909 by C. D. Walcott (see Conway Morris and Whittington, 1979; Whittington, 1980). Exceptional preservation of many kinds of soft-bodied organisms in association with shelly animals provides an unusual wealth of information about an ancient marine community (Conway Morris, 1979). It has been noted that the structure of the Burgess shale community will have wider interest if it can be shown that the biota is exceptional only

in conditions of fossilization rather than in original composition (Conway Morris, 1981). During recent years, rare representatives of several Burgess shale taxa with low potential for preservation have been discovered in the western United States. The purpose of this paper is to document additional specimens of one of these taxa, the unusual trilobite *Naraoia compacta* Walcott, 1912. Five other taxa are documented in an accompanying paper by Briggs and Robison (1984).

Six specimens of *Naraoia compacta* are known from Cambrian strata in Idaho and Utah. In 1963, a single exoskeleton was collected from the Gibson Jack Formation near Pocatello,

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Idaho, by D. E. Trimble and later identified as *Naraoia* by A. R. Palmer (Trimble, 1976:28). Loan of that specimen for this study was arranged by M. E. Taylor of the U. S. Geological Survey. In 1982, a second specimen was collected from the same formation at a nearby but stratigraphically higher locality by M. B. and L. B. McCollum. During recent years four other specimens of *N. compacta* were collected from a single locality in the Marjum Formation of the House Range, Utah, by Lloyd and Metta Gunther and T. T. Johnson. All six specimens are deposited with collections of the U. S. National Museum of Natural History in Washington, D. C.

**Terminology.**—In his monograph on *Naraoia*, Whittington (1977:411) did not use morphological terms applicable to other trilobites (e.g., pygidium) “because of their implications and because the currently accepted definitions . . .

would require amendment.” I sympathize with that approach; however, for ease of discussion I shall refer to the anterior tagma of *Naraoia* as the *cephalon* and the posterior tagma as the *pygidium*. These terms are used with no implications of homology.

**Acknowledgments.**—Contributions of specimens by Lloyd and Metta Gunther, M. B. and L. B. McCollum, and T. T. Johnson are much appreciated. During this study, helpful information and suggestions were received from Jan Bergström, D. E. G. Briggs, Simon Conway Morris, and M. B. and L. B. McCollum. Some of Lloyd and Metta Gunther’s collecting expenses were paid by National Science Foundation grant EAR-8201428 to J. Keith Rigby of Brigham Young University. Some publication costs were paid by NSF grant EAR-8024066 to the author.

## SYSTEMATIC PALEONTOLOGY

Class TRILOBITA Walch, 1771

### Order NEKTASPIDA Raymond, 1920

[*nom. correct.* herein, *pro* order Nektaspia RAYMOND, 1920:148]  
[= Nectaspida STÖRMER, 1959:O30]

**Diagnosis.**—Eyeless trilobites characterized by only two uncalcified tagmata divided by a single transverse articulation. Except for raised axial lobe, dorsal surface of exoskeleton smooth and unfurrowed.

**Discussion.**—In 1920, Raymond concluded that representatives of *Naraoia* were trilobites and he named the order Nektaspia to include that unusual genus. Recently, Whittington (1977) has thoroughly analyzed the morphology of *Naraoia* and has reviewed its affinities. Disagreeing with some earlier workers (e.g., Walcott, 1912; Henriksen, 1928; Störmer, 1959), Whittington presented a strong argument in support of Raymond’s assignment of *Naraoia* to the Trilobita. Although *Naraoia* possesses some unusual characters for a member of the Trilobita, I provisionally accept its assignment to that class.

Repina and Okuneva (1969) described two new genera, *Maritimella* and *Orientella*, which they assigned to the Nektaspida. The few speci-

mens on which those genera are based appear to be pseudofossils formed by desiccation and curling of thin films of sediment (compare Teichert and Hakes in Häntzschel, 1975: fig. 101). If true, *Naraoia* remains as the only valid genus representing the order Nektaspida.

Family NARAOIIDAE Walcott, 1912

### Genus NARAOIA Walcott, 1912

Characters of the order.

### NARAOIA COMPACTA Walcott, 1912

Figures 1-3

*Naraoia compacta* WALCOTT, 1912, p. 175-177, pl. 28, figs. 3, 4; 1931, p. 9-14, text-figs. 1, 2; pl. 13, fig. 4; pl. 14, figs. 1-3; pl. 15, figs. 2, 3; RAYMOND, 1920, p. 139-140, fig. 36; HENRIKSEN, 1928, p. 11; SIMONETTA and DELLE CAVE, 1975, p. 4, pl. 5, fig. 9; pl. 33, figs. 1-3, 5, 10; pl. 34, figs. 1-7; pl. 35, figs. 1-6; WHITTINGTON, 1977, p. 409-432, 433-440, figs. 1-90, 94-99; 1980, p. 135, text-fig. 5F-H; pl. 1, fig. 5; 1982, p. 14, fig. G.  
*Naraoia halia* SIMONETTA and DELLE CAVE, 1975, p. 5, pl. 5, fig. 12; pl. 35, fig. 7.

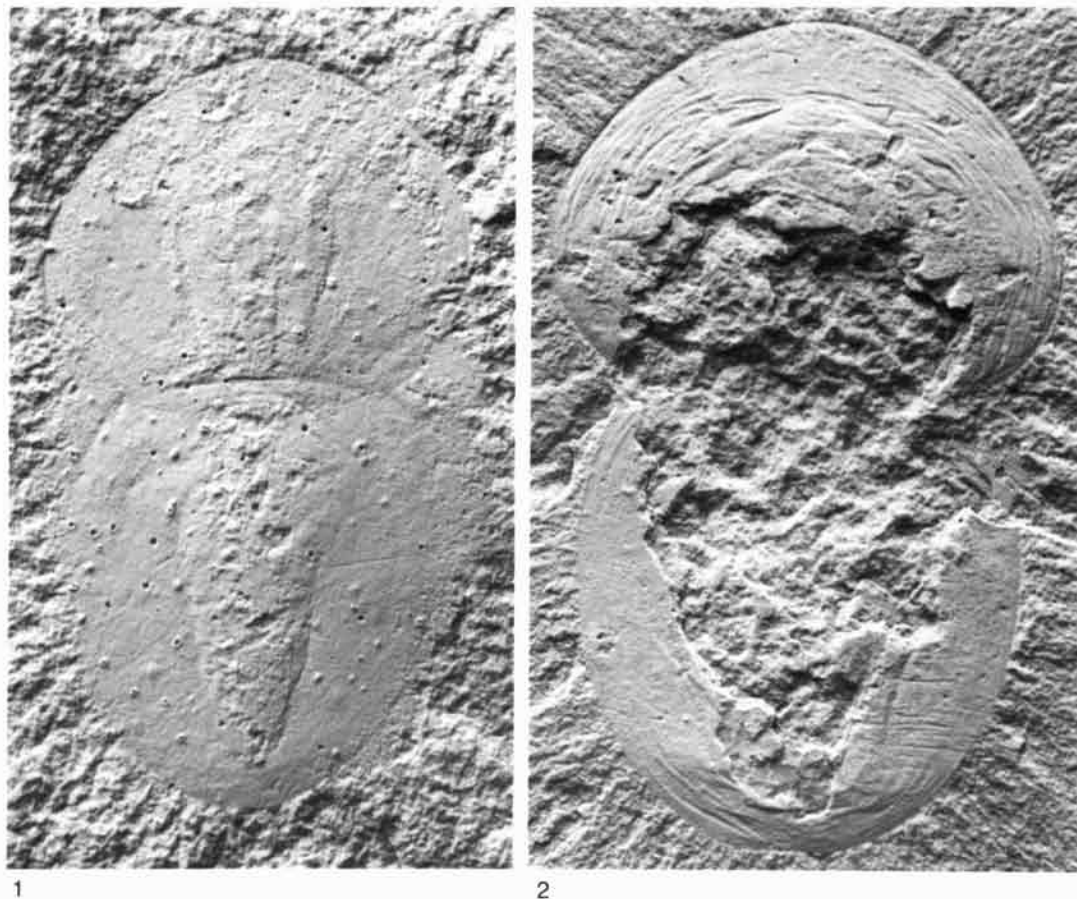


Fig. 1. *Naraoia compacta* Walcott from the Gibson Jack Formation, Bannock Range, Idaho. The specimens have been lightly coated with magnesium oxide and photographed in low, oblique light. Random pustules on both specimens appear to contain pseudomorphs of goethite after pyrite. 1. Dorsal exoskeleton that may possess poorly preserved posterolateral spines on the cephalon; USNM 358003 from member A,  $\times 5$ . 2. Incomplete dorsal exoskeleton without posterolateral spines on the cephalon; USNM 376685 from member C,  $\times 4$ .

*Naraoia pammon* SIMONETTA and DELLE CAVE, 1975, p. 5, pl. 5, fig. 11; pl. 35, fig. 8.

**Lectotype.**—Specimen with appendages (USNM 57687), designated by Whittington (1977:417, figs. 5-8).

**Diagnosis.**—Representatives of *Naraoia* lacking spines on pygidial margin. Short posterolateral spines on cephalon may be present or absent.

**Described material.**—The concept of *N. compacta* has been previously based on more than 100 specimens, all from the Burgess shale at its type locality. Those specimens, many preserving appendages and features of internal anat-

omy, have been recently described in detail and many have been illustrated with excellent photographs and interpretive drawings by Whittington (1977).

**New material.**—Six specimens, all preserved in shale, here are assigned to *N. compacta*. Two are dorsal exoskeletons from the Gibson Jack Formation of possible late Early Cambrian age in southeastern Idaho. Four specimens, all showing features of internal anatomy and one showing poorly preserved appendages, are from the Marjum Formation of late Middle Cambrian age in west-central Utah.

The two dorsal exoskeletons (Fig. 1) from the Gibson Jack Formation do not show associ-

ated appendages, but they are otherwise closely similar to specimens of *N. compacta* from the Burgess shale. Fossils from both units are preserved as flat compressions in shale. Plotted positions of measurements (Table 1) from the two Gibson Jack specimens fall well within the variation fields of Burgess specimens that were measured by Whittington (1977: fig. 2c-e). Thus, there is no statistical support for treating them as other than conspecific.

Table 1. *Measurements of Specimens of Naraoia compacta Walcott from Idaho and Utah.* (Measurements in millimeters; estimates based on incompletely preserved or exposed features in parentheses.)

| Measured Features   | Idaho<br>Gibson Jack<br>Formation |                | Utah<br>Marjum<br>Formation |
|---------------------|-----------------------------------|----------------|-----------------------------|
|                     | USNM<br>358003                    | USNM<br>376685 | USNM<br>366080              |
| Exoskeleton, length | 19.3                              | 26.5           | 28.5                        |
| Cephalon, length    | 9.5                               | (13)           | (13)                        |
| width               | 11.3                              | 16.6           | 20.0                        |
| Pygidium, length    | 11.1                              | (15)           | 17.7                        |
| width               | 10.8                              | 14.3           | (17)                        |

Whittington (1977:418) has discussed evidence for dimorphism in *N. compacta*. About one-fifth of the Burgess shale specimens possess short posterolateral spines on the cephalon. According to Whittington, measurements from the entire sample provide no further evidence of dimorphism, and he did not consider the cephalic spines to be an adequate basis for distinct species. Of the two specimens from the Gibson Jack Formation, one (Fig. 1,2) lacks spines, whereas the other (Fig. 1,1) may possess poorly preserved cephalic spines.

In his reconstruction of a nonspinose specimen of *N. compacta*, Whittington (1977: fig. 96a) showed the axis of the cephalon to be widest near its posterior and to taper forward. The specimen from the Gibson Jack Formation with possible cephalic spines (Fig. 1,1) has an axis that is widest about midway along the cephalon, and it tapers posteriorly and is undefined anteriorly. Illustrated Burgess shale morphs with cephalic spines (Whittington, 1977: figs. 49, 50, 60-62) also appear to have

axes that are widest near the cephalic midlength. Because axial shape may have been deformed by compaction, I tentatively follow Whittington in assigning both morphs to *N. compacta*.

Other features of specimens from the Gibson Jack Formation are in close accord with those of *N. compacta* from the Burgess shale. The well-rounded posterior margin of the cephalon overlaps the less rounded anterior margin of the pygidium; however, compression has partially obscured the posterior cephalic margin. The covered, anterior pygidial margin is indicated by a narrow, shallow furrow that has been secondarily impressed across the posterior cephalon (Fig. 1,1). A pair of weak longitudinal furrows on the cephalic axis may mark the impression of an underlying sediment-filled gut (compare Fig. 1,1 with Whittington, 1977: figs. 49, 54, 64, 74, 87). Concentric wrinkles paralleling exterior margins (Fig. 1,2) indicate post-burial compression and plastic deformation of a moderately convex exoskeleton.

Of the four specimens from the Marjum Formation, the best preserved one (USNM 366080) is compacted dorsoventrally with the horizontal plane of the body parallel to bedding. When the matrix was broken the compacted body was horizontally cleaved, exposing remarkably different anatomical features on the part and counterpart (Fig. 2). A thin, light-brown film representing the uncalcified dorsal exoskeleton adheres to the counterpart (Fig. 2,1). The interior surface shows a variety of dark markings in the axial region. Some of the laterally paired marks probably represent sites of insertion for extrinsic limb muscles (compare cephalocarid muscle patterns, Hessler, 1964: fig. 5). Similar, serially arranged marks suggest that 3 pairs of limb muscles attached ventrally to the cephalon and 16 pairs to the pygidium, which accords with the numbers of biramous limbs documented for *N. compacta* from the Burgess shale (Whittington, 1977). More anterior, wider spaced, smaller, and less clear marks on the cephalon may represent sites of insertion for extrinsic antennal muscles. The part (Fig. 2,2) shows portions of the alimentary system, particularly the midgut beneath the cephalon. A pair of large, highly ramified diverticula extends laterally from the alimentary canal, originating slightly in advance of the midlength of the cephalon. Each diverticular trunk bifur-

cates into two secondary branches, one running forward and the other outward and backward. The secondary branches further ramify into fanned arrays of numerous, rather evenly spaced, blind tubules. Three pairs of smaller, irregularly shaped diverticula are laterally directed from the alimentary canal beneath the back part of the cephalon. In general, features of the midgut agree closely with Whittington's (1977:423) detailed description based on Burgess shale specimens. The only noteworthy difference is that the three posterior pairs of cephalic diverticula are not uniformly ramified as suggested by Whittington's (1977: fig. 96) reconstruction; however, the diverticula are not

so well preserved on Burgess specimens as they are on the Marjum specimen. Plotted positions of measurements of the specimen (Table 1) also fall well within the variation fields recorded for Burgess specimens (Whittington, 1977: fig. 2c-e).

Two specimens (USNM 376687, 376688) from the Marjum Formation are preserved with the pygidium in a parallel oblique attitude and the cephalon either folded underneath (Fig. 3,2) or flexed steeply downward. The hindgut is shown as a medial dark trace on both specimens. One (Fig. 3,2) shows rather clearly a segmental series of paired, unramified, lateral diverticula. Sharply defined, narrow, black

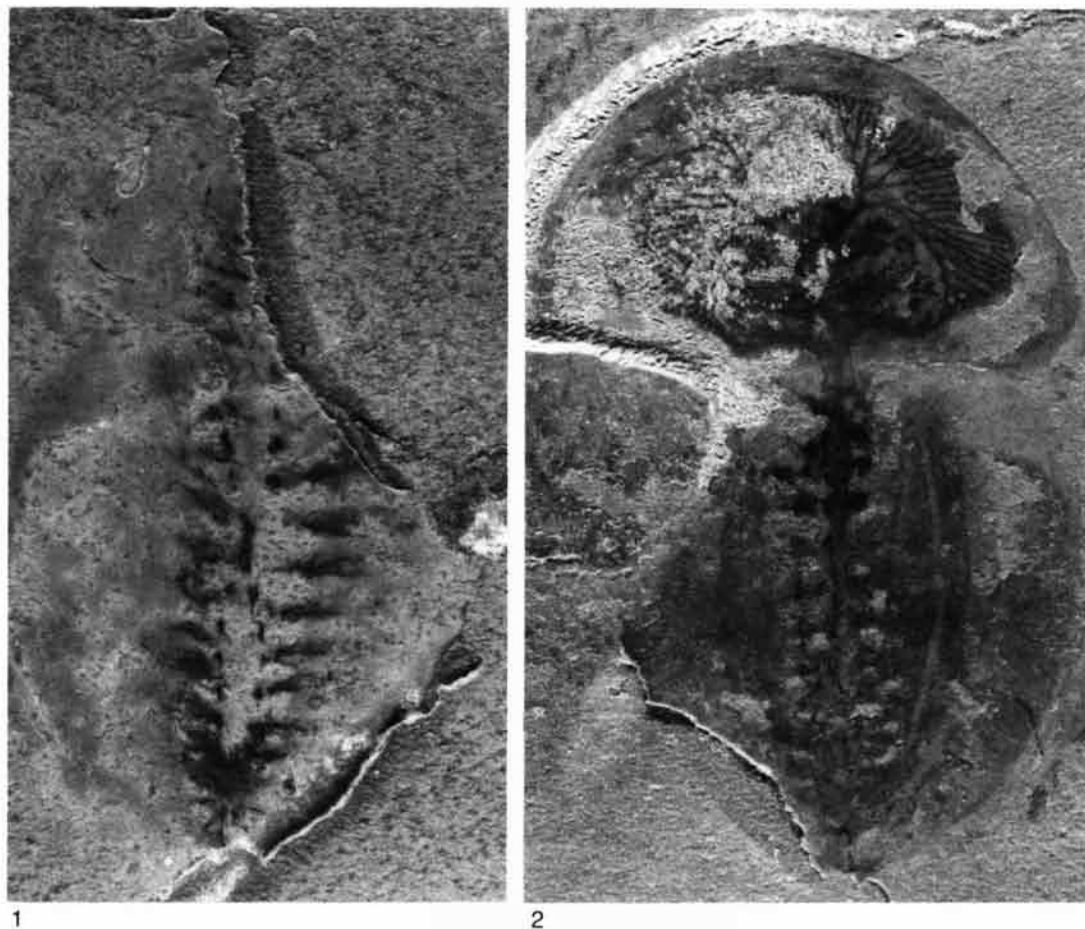


Fig. 2. *Naraoia compacta* Walcott from the Marjum Formation, House Range, Utah; USNM 366080,  $\times 4$ . 1. Counterpart showing ventral surface of exoskeleton with dark markings in the axial region. 2. Part showing portions of the alimentary system, two types of midgut diverticula being particularly well preserved in the right cephalic region.



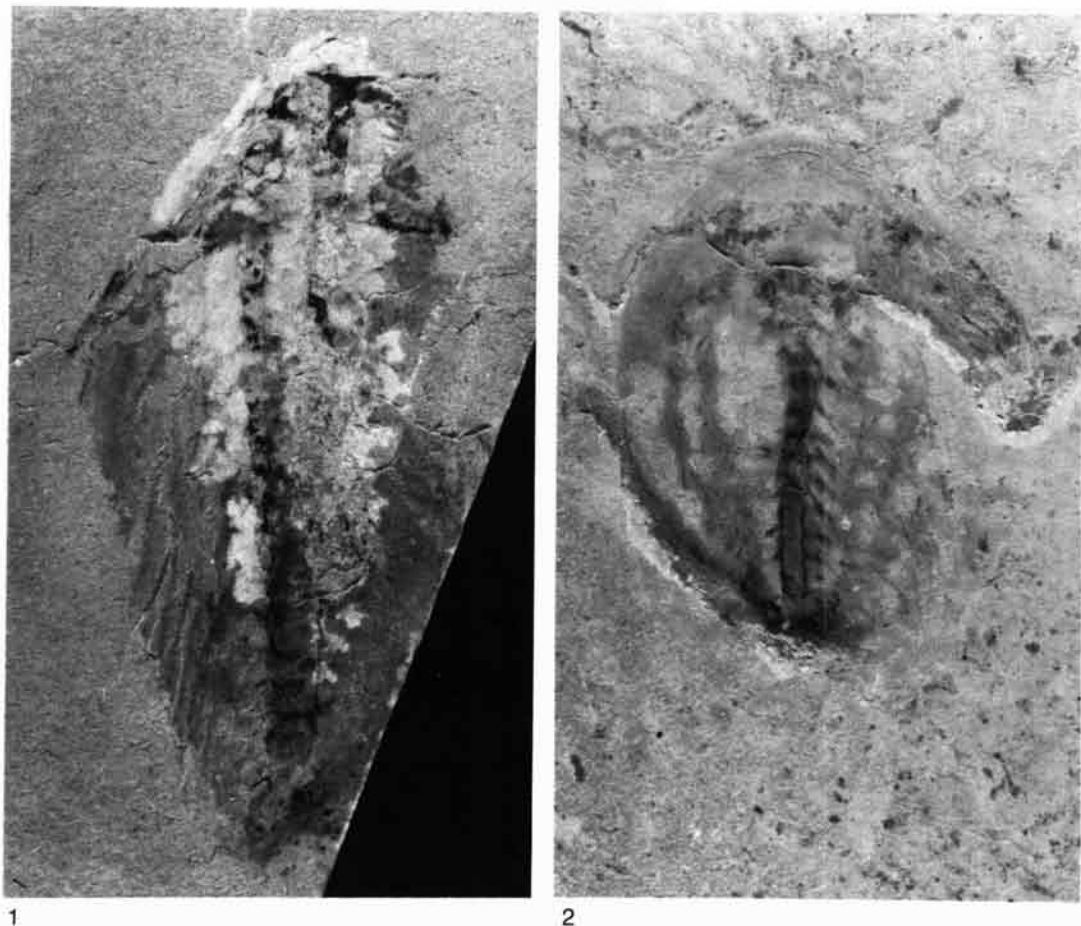


Fig. 3. *Naraoia compacta* Walcott from the Marjum Formation, House Range, Utah; both  $\times 3$ . 1. USNM 376686 showing lateral, poorly preserved, serial appendages and medial, dark trace of alimentary canal. 2. USNM 376687 showing hindgut with segmentally paired, unramified diverticula beneath pygidium. Cephalon is folded beneath the pygidium and its curved posterior margin is at the top of the picture. Excavation beneath the right side of the cephalon has exposed some of the large ramified diverticulum.

lines bounding the posterior hindgut may represent a chitinous lining (Fig. 3,2), as is common among modern arthropods. Both specimens show some of the large ramified diverticula beneath the cephalon.

A fourth specimen (USNM 376686) from the Marjum Formation is preserved mostly in parallel attitude but is deformed around the anterior cephalic margin (Fig. 3,1). It differs from other Marjum specimens by showing a long series of overlapping lamellar appendages along the lateral margins. Preservation is inadequate to reveal structural details of the individual appendages. The alimentary canal is

indicated by a medial dark trace.

*Remarks.*—Specimens of *Naraoia compacta*, which have a smooth pygidial margin, can be easily differentiated from those of *N. spinifer* Walcott, 1931, which have a stout median spine and seven pairs of lateral spines on the pygidial margin. I concur with Whittington (1977) in considering *N. halia* Simonetta and Delle Cave, 1975, and *N. pammon* Simonetta and Delle Cave, 1975, to be junior subjective synonyms of *N. compacta*.

The presence of *Naraoia* in Idaho and Utah supports the notion that the Burgess shale biota is exceptional only in the conditions of its

preservation (see Conway Morris, 1981). Additional specimens of *Naraoia* have recently been reported from two new localities in the Stephen Formation of British Columbia (Collins, Briggs, and Conway Morris, 1983). These, together with specimens described here, demonstrate that *N. compacta* was widely distributed in open-shelf environments along western North America during the Cambrian Period.

**Occurrence.**—Two specimens of *Naraoia compacta* are preserved in grayish-olive, siliceous shale of the Gibson Jack Formation of the Bannock Range, about 7 km south of Pocatello, Bannock County, Idaho. USNM 358003 was collected by D. E. Trimble (1976:28) near the top of member A at U. S. Geological Survey locality 4312-CO on a small ridge just south of Gibson Jack Creek. Trimble reported the locality to be in the SE $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 27, T. 7 S., R. 34 E.; however, subsequent unpublished mapping by M. B. and L. B. McCollum (letter, 1983) indicates that the locality is in the NW $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 27 (Pocatello South 7 $\frac{1}{2}$ -minute quadrangle map, U. S. Geological Survey, 1971). A second specimen, USNM 376685, was collected by the McCollums from approximately 50 m above the base of member C, just north of Gibson Jack Creek. That locality is in the SE $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 27 and is about 0.6 km east-northeast of locality 4312-CO. Associated fossils do not provide close biostratigraphic control on the age of the two *Naraoia* specimens. Trimble (1976:28) reported only *Protospongia* from the same area. Based on the presence of *Olenellus* in a similar stratigraphic section in the Fish Creek Range, about 50 km to the southeast, Crittenden and others (1971:587) and

Trimble (1976:28) concluded that the Gibson Jack Formation is late Early Cambrian in age.

Four specimens of *N. compacta* are from the Marjum Formation of the House Range, Millard County, Utah. Three of these (USNM 366080, 376687, 376688) were collected by Lloyd and Metta Gunther, and one (USNM 376686) was collected by T. T. Johnson. All specimens are preserved in yellowish-gray to pale-yellowish-brown, platy parting, laminated, calcareous clayshale and are from about 60 m above the base of the formation. The locality (347 of Robison; 3 of Rigby, 1983:243), informally called Sponge Gully, is in a dry stream gully about 4.7 km east-northeast of Marjum Pass in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 4 (unsurveyed), T. 18 S., R. 13 W. (Marjum Pass 7 $\frac{1}{2}$ -minute quadrangle map, U. S. Geological Survey, 1972). A diverse associated biota of the *Ptychagnostus punctuosus* Zone is listed in an accompanying paper by Briggs and Robison (1984).

As presently known, *N. compacta* has observed stratigraphic and geographic ranges from the Burgess shale of the Stephen Formation (*Ptychagnostus praecurrens* Zone, lower Middle Cambrian) in British Columbia to the lower Marjum Formation (*Ptychagnostus punctuosus* Zone, upper Middle Cambrian) in Utah. If the inferred age of specimens in the Gibson Jack Formation of Idaho can be confirmed, it will extend the observed stratigraphic range of *N. compacta* downward to the *Olenellus* Zone (upper Lower Cambrian).

These occurrences show *N. compacta* to have, compared to most Cambrian trilobite species, an unusually long stratigraphic range.

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