Review of the geology and paleontology of the Ellsworth Mountains, Antarctica

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Abstract The geology of the Ellsworth Mountains has become known in detail only within the past 40-45 years, and the wealth of paleontologic information within the past 25 years. The mountains are an anomaly, structurally speaking, occurring at right angles to the Transantarctic Mountains, implying a crustal plate rotation to reach the present location. Paleontologic affinities with other parts of Gondwanaland are evident, with nearly 150 fossil species ranging in age from Early Cambrian to Permian, with the majority from the Heritage Range. Trilobites and mollusks comprise most of the fauna discovered and identified, including many new genera and species. A *Glossopteris* flora of Permian age provides a comparison with other Gondwana floras of similar age. The quartzitic rocks that form much of the Sentinel Range have been sculpted by glacial erosion into spectacular alpine topography, resulting in eight of the highest peaks in Antarctica.

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Introduction

The Ellsworth Mountains are located in West Antarctica (Figure 1) with dimensions of approximately 350 km long and 80 km wide. They are divided by the east-flowing Minnesota Glacier into the Sentinel Range to the north and the Heritage Range to the south. The rugged topography is evident by alpine features eroded from quartzitic rocks that exhibit the highest peaks in Antarctica, with 8 peaks between 4359 and 4892 m in elevation (Gildea and Splettstoesser, 2007). The more than 13,000-m-thick stratigraphic succession ranges in age from Cambrian to Permian, and exhibits similarities to other Gondwana sequences in the southern hemisphere and India. Glacial deposits, coal beds, and plants of Permian age are parts of this common sequence, including the first occurrence of *Glossopteris* in West Antarctica (Craddock et al., 1965). The abundance and variety of fossils in the Cambrian and Devonian sequences are unique, with numerous new genera and species of mollusks and other fauna figured and named.

No obvious basement rocks have been discovered, although Precambrian rocks are presumably at depth, as indicated by a Precambrian age of the nearby Haag Nunatak (77°S, 78°18'W) (Clarkson and Brook, 1977). A U-Pb zircon date of 512 ± 14 Ma in volcanic rocks of the Union Glacier Formation (Rees et al., 1997, suggests that the rocks that were intruded could be Precambrian in age.

An alignment with a similar sequence in the nearby Transantarctic Mountains, however, is not shown, with the strike of the Ellsworth Mountains at nearly right angles to the former, as well as to the Antarctic Peninsula to the northwest. The movement of the Ellsworth Mountains, along with the nunataks to the south (Pirrit, Nash, and Martin Hills; Whitmore Mountains; Pagano Nunatak), denoted here as the EWM crustal block, as a microplate and concurrent uplift, has been analyzed by several investigators, with many reconstructions proposed

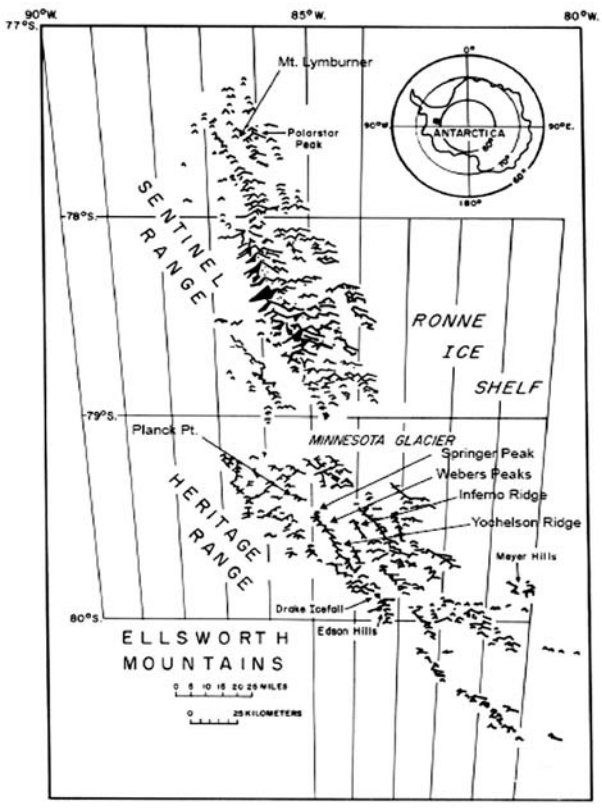

Figure 1. General location map of the Ellsworth Mountains (modified from original sketch map by J.J. Anderson in Anderson et al., 1962).

(see Webers et al., 1992, p. 6 for a summary). Over half of the stratigraphic column (Figure 2) was deposited during the Cambrian, when volcaniclastic sediments were deposited in a rift basin on the margin of Gondwana. Following the Cambrian the Ellsworth basin became a slowly subsiding, semi-stable sedimentary region. The

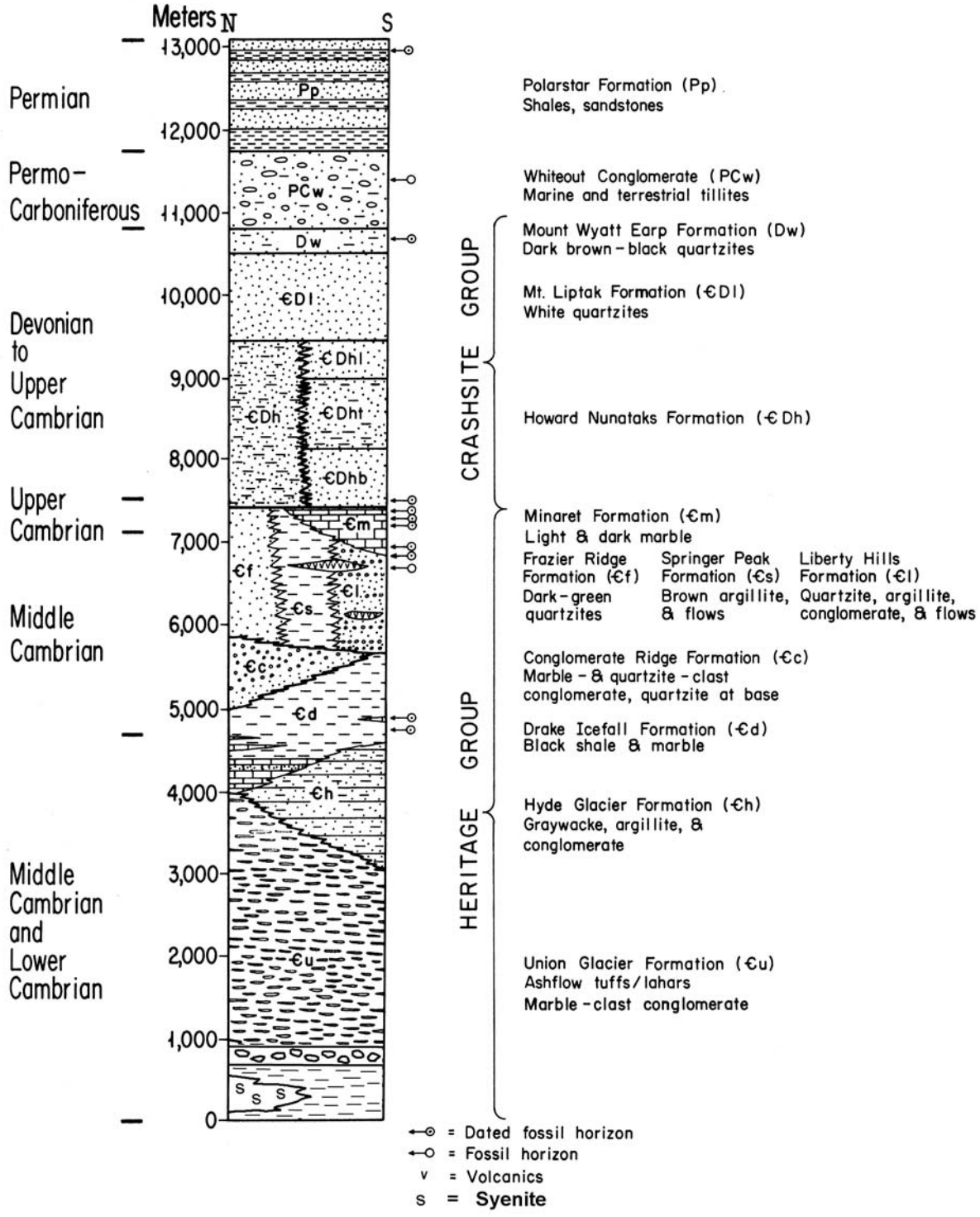

Figure 2. Columnar section of the Paleozoic rocks exposed in the Ellsworth Mountains, West Antarctica.

Ellsworth Mountains sequence was deformed and metamorphosed in Early Jurassic time (Craddock, 1969).

Paleontologic history

Geologic investigations in the Ellsworth Mountains have yielded a treasure-trove of paleontological information. Twenty-seven localities have yielded 17 fossil faunas and one fossil flora. These sites exhibit 148 species ranging in age from Early Cambrian to Permian. The majority of the fossil sites are in the Heritage Range. The reader is referred to the volume on "Geology and Paleontology of the Ellsworth Mountains, West

Table 1 Major fossil faunas/floras from the Ellsworth Mountains, West Antarctica.

Localities	Formation	Age	Lithology	Dominant Fossils	Comments	References*
Polarstar Peak	Polarstar	Permian	Argillite & Sandstone	*Glossopteris* Flora	Typical Flora	Taylor & Taylor p.285-294
Planck Point	Mount Wyatt Earp	Devonian	Quartzite	Inarticulate Brachiopods	Diverse but Sparse Fauna	Webers et al. p. 269-278
Springer Peak & Webers Peaks	Minaret	Late Cambrian	Limestone	Trilobites & Molluscs	Spectacular Fauna	Webers et al. p. 181-248
"	"	"	"	Conodonts	Recrystallized	Buggisch et al. p.169-179
"	"	"	"	Brachiopods Pelmatozoa Archaeo-cyathids	Mostly Inarticulate Brachiopods	Henderson et al. p. 249-267
"	"	"	"	Trilobites	Abundant Fauna	Shergold & Webers p. 125-168
Yochelson Ridge	Minaret	Middle Cambrian	Limestone	Trilobites	Abundant Fauna	Jago & Webers p. 101-124
Meyer Hills	Whiteout Conglomerate	Early Cambrian	Carbonate Clasts	Archaeo-cyathids	Archaeo-cyathan Fauna from Clasts	Debrenne p. 279-284
Mt. Lymburner	"	"	"	"	"	"
Edson Hills	Drake Icefall	Early Cambrian	Carbonate Clasts Algae	Archaeo-cyathids & Skeletal	Sparse Fauna/ Flora	Buggisch & Webers p. 81-100

* References are from Webers et al. (1992)

Antarctica" (Webers et al., 1992) for details on the fossils described below. Table 1 lists major fossil faunas/floras from the Ellsworth Mountains, and Figure 3 illustrates representative fossils.

The Late Cambrian trilobite-mollusk fauna at Springer Peak is truly remarkable. It is perhaps the best preserved and most diverse of any fauna of Late Cambrian age anywhere in the world. Seven phyla are represented, including Arthropoda, Mollusca, Brachiopoda, Hyolitha, Echinodermata, Pisces, and Archaeocyatha. Some 70 species are present. The fauna is found in an 8-m-thick feather-edge of the Minaret Formation that thickens to as much as 600 m to the south. To the south, severe deformation has generally destroyed the fossils. At Springer Peak the feather-edge was bounded above and below by incompetent argillites which took up the deformational strain. The fossils are three-dimensional. Preservation is excellent and shells are present. Much of the material is a coquina of fossils. Space does not permit illustration of this remarkable fauna.

Trilobites make up the majority of the material with about 8% being made up of mollusks. Twenty species of trilobites, including agnostids, show affinities to North America, Australia, China and southern Russia. The mollusks are perhaps the most noteworthy. They include seven species of monoplacophora, six species of gastropods, three species of rostroconchs and an orthothecid.

The monoplacs (monoplacophorans) are perhaps the most significant. They are generally very rare in Late Cambrian faunas. At Springer Peak they are present in great numbers and diversity. We believe that the monoplacs are ancestral to the cephalopods, rostroconchs, bivalves, and gastropods.

Monoplacs are typically low, cap-shaped, single shells. The Springer Peak monoplacs also contain a number of high-coned forms. We believe one of these, *Knightoconus* (Yochelson et al., 1973) to be representative of a group that is ancestral to the cephalopods. It is a high-coned, multiseptate species but lacks the siphuncle of the cephalopods (Figure 3, no.6). The first known cephalopods are slightly younger and are from China. They are a little more elongate than *Knightoconus* and have a small siphuncle along the ventral margin. Both forms are multiseptate and curved in a similar manner.

Six species of gastropods and three species of rostroconchs are present. Rostroconchs are clam-like in appearance but have only one shell. Rostroconchs probably lived like modern clams. A single species of an orthothecid was also recovered.

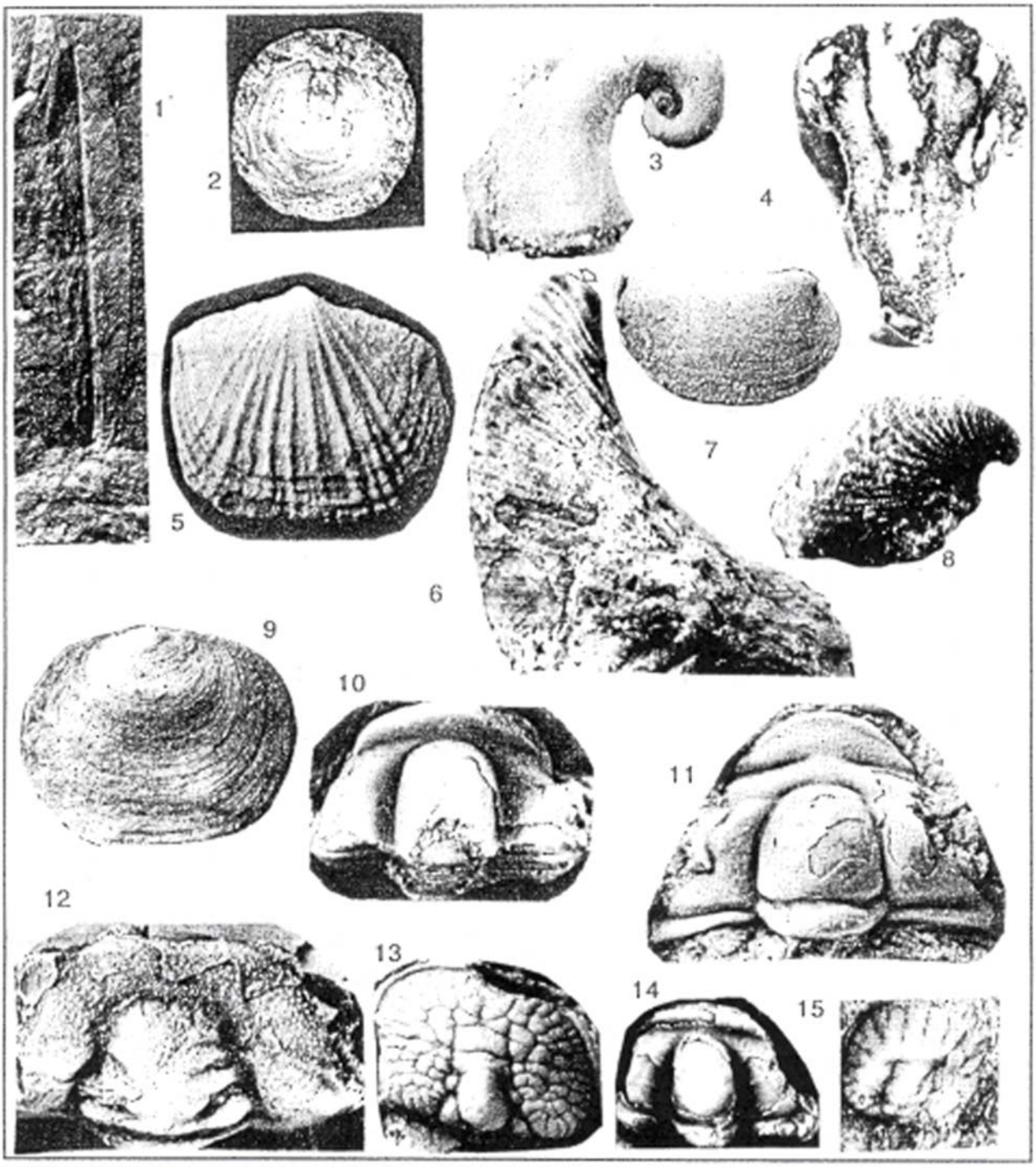

Figure 3. Representative Fossils from the Ellsworth Mountains (from Webers et al. (1992). 1. *Glossopteris cf. tortuosa,* x 2, Chap. 14, Pl. 1, p. 291; 2. *Orbiculoidea cf. falklandensis*, x1.5, Chap. 12, Pl. 1, p. 277; 3. *Euomphalopsis splettstoesseri*, x3, Chap. 10, Pl. 7, Fig. 11, p. 221; 4. *Antarcticocyathus webersi*, x2.5, Chap. 11, Pl. 5, Fig. 1, p.267; 5. *Billingsella cf. borukaev*i, x3.5, Chap. 11, Pl. 4, Fig. 5, p. 265; 6. *Knightoconus antarcticus*, x3, Chap. 10, Pl. 16, Fig. 2, p. 239; 7. *Ribeiria australiensi*s, x10, Chap. 10, Pl. 1, Fig. 9, p. 209; 8. *Proplina rutfordi*, x10, Chap, 10, Pl. 12, Fig. 13, p. 231; 9. *Angulotreta ellsworthensis*, x30, Chap. 11, Pl. 1, Fig. 1, p. 259; 10. *Sohoplura drakensis*, x6, Chap. 7, Pl. 3, Fig. 1, p. 119; 11. *Onchopeltis? cf. neutra*, x6, Chap. 8, Pl. 5, Fig. 7, p. 155; 12. *Pseudobergeronites spinosa*, x3, Chap. 7, Pl. 4, Fig. 5, p. 121; 13. *Glyptagnostus reticulatus*, x6, Chap. 8, Pl. 2, Fig. 14, p. 149; 14. *Pagetia edsonensis*, x3.4, Chap. 7, Pl. 2, Fig. 24, p. 117; 15. *Tomagnostella sp*., x8, Chap. 7, Pl. 2, Fig. 1, p. 117.

Late Cambrian mollusks are geographically widespread in China, Australia and North America. The Minaret mollusks are closest to a molluskan fauna found at Taylors Falls, Minnesota, U.S.A. The Minnesota material, however, is poorly preserved in sandstone as internal and external molds.

In addition to the mollusks and the trilobites, a variety of other forms are present in the Minaret fauna. Archaeocyathids were thought to be confined to the Lower Cambrian. The Minaret fauna contains the first-known Late Cambrian archaeocyathid. Scattered columnals of pelmatozoa are present and cover some bedding surfaces. Nine species of inarticulate brachiopods and a single species of articulate brachiopod are present. Ten species of conodonts were also recovered. Trilobite faunas were also collected from five localities (Springer Peak, Pojeta Peak, Drake Icefall area, Edson Hills, and Yochelson Ridge) by M.N. Rees (personal communication, 2006) during expeditions in 1993 and 1995. Descriptions of these faunas have not been published.

A Lower Devonian fauna has been recovered near Planck Point in the Heritage Range. The fauna is diverse but rather sparse. The inarticulate brachiopod *Orbiculoidea cf. falklandensis* (Webers et al., 1992) is the most common fossil. Other forms present include two species of bivalves, and one species each of a cephalopod, rostroconch, gastropod, conularid, trilobite, and articulate brachiopod. A single fish spine was recovered. The fauna correlates with those of the Lower Devonian of the Horlick Formation, Ohio Range, Horlick Mountains, and the Lower Devonian of the Falkland Islands.

A Middle-to-Late Permian flora has been collected from four localities of the Polarstar Formation in the northern Sentinel Range. This is the so-called *Glossopteris* flora. Fifteen species of *Glossopteris* dominate the flora. Two species of *Gangamopteris* are also present, as are two species of Sphenophyta. An insect wing was also recovered (Tasch and Riek, 1965).

The flora in the Ellsworth Mountains appear most similar to floras from the Ohio Range of the Horlick Mountains, the Theron Mountains, Whichaway Nunataks, southern Victoria Land, and the Falkland Islands.

Summary

The faunas and flora of the Ellsworth Mountains have provided abundant information on evolution, environmental conditions, and dating. Correlation of these fossils with the Ohio Range of the Horlick Mountains seems to be the most consistent, and fits in well with the theory that the Ellsworth Mountains once occupied a position adjacent to the Pensacola Mountains of the Transantarctic Mountains.

Acknowledgments. This article is dedicated to Campbell Craddock (deceased 23 July 2006), who led the way toward significant discoveries in the Ellsworth Mountains, Antarctica, and to Ellis Yochelson (deceased 30 August 2006), a major contributor toward field collecting and identification of many of the fossils described in Webers et al. (1992). Editorial assistance and advice from W. LeMasurier are appreciated, as well as initiating the special session for C. Craddock. The manuscript benefited from reviews by J. Collinson, J. Craddock, and R. Ojakangas.

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