Field workshop
„Precambrian-Cambrian boundary, Ediacara biota, Snowball Earth deposits, and the geology of the Nama basin around Aus (Southern Namibia)"

March, 4, 2019 to March, 12, 2019

Ulf Linnemann, Pat Vickers-Rich, Maria Ovtcharova,
Andreas Gärtner, Mandy Hofmann, Johannes Zieger

Cover image:

Top: view to Swartkloof mountain (Farm Swartkloof)
Bottom: View from Swartkloof mountain (Farm Swartkloof)
Pictures by Ulf Linnemann

ACKNOWLEDGEMENT

Introduction to the field area by K.H. Hoffmann (Windhoek, Namibia) and fruitful discussions including important suggestions by B. Saylor (Case Western Reserve University, Cleveland, USA) for are greatly acknowledged. We further thank L. and B. Roemer, L. Gressert, and B. Boehm-Ernie from Aus, Namibia, for support during our fieldwork. Sincere thanks go to the Geological Survey of Namibia, particularly to G. Schneider, for facilitating our work, and to the National Geographic Society for support of fieldwork in southern Namibia since 2004. We acknowledge long-term funding of the geochronology facility at University of Geneva through the Swiss National Science Foundation. Further, we appreciate long-term funding of the GeoPlasmaLab Dresden by the Senckenberg Naturforschende Gesellschaft and the Deutsche Forschungsgemeinschaft. This project is part of UNESCO International Geosciences Program IGCP587 and IGCP493.

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22	Kombada Mhopjeni	Windhoek, Namibia

HOTEL in WINDHOEK:

The nights in Windhoek we will spend in a pension:

Hotel Pension Christoph, Heinitzburgstr. 33 / Ecke Robert Mugabe Ave., P.O.Box 6116, Ausspannplatz, Windhoek/Namibia, http://www.natron.net/tour/christoph/

Here, we will have mostly double rooms (not so much single rooms available).

HOTEL in AUS:

For the nights in Aus we booked single rooms in the Bahnhof Hotel:

Bahnhof Hotel, 20 Lüderitz Street, Aus, South West Namibia, Frontdesk Phone number: +264 63 258-091, http://hotel-aus.com/contacts/

The day of arrival is March, 4, 2019.

The meeting point is Hotel Pension Christoph in Windhoek.

The airport is far outside Windhoek and we try to pick you up. Alternatively, you can take a taxi.

Excursion plan (details can change due to the actual situation):

March 4: day of arrival, in the afternoon visit of the Geological Survey (6 Aviation Road Private Bag 13297, Windhoek, Namibia, Tel: +264-61-284 8111, Fax: +264-61-238643/ 220386, Email: info@mme.gov.na)

3.00 pm: Introduction and visit of the collections (Helke Mocke, Pat Vickers-Rich, Ulf Linnemann)
If you would like to buy the book "Geology of Namibia" (3 heavy volumes), please bring about 1600 N$ cash. No credit cards accepted.
5.30 pm: Open lecture of Axel Gerdes "U-Pb dating of limestone"
Overnight stay: Hotel Pension Christoph

March, 5: drive to Aus (700 km), some outcrops on the road side
Overnight stay: Bahnhof Hotel Aus

March, 6: Snowball Earth sediments around Rosh Pina
Overnight stay: Bahnhof Hotel Aus

March, 7: Precambrian-Cambrian boundary at farm Swartpunt
Overnight stay: Bahnhof Hotel Aus

March, 8: Precambrian-Cambrian contact at farm Swartkloofberg
Overnight stay: Bahnhof Hotel Aus

March, 9: Ediacaran sediments and fossils at farm Aar
Overnight stay: Bahnhof Hotel Aus

March, 10: Ediacaran sections at farms Anusi and Pockenbank
Overnight stay: Bahnhof Hotel Aus

March, 11: drive back to Windhoek (700 km), some outcrops at the roadside
Overnight stay: Hotel Pension Christoph

March, 12: day of departure

Introduction to the Nama group, underlying strata of the Port Nolloth group, and the Precambrian-Cambrian boundary

The Nama group in southern Namibia (Figs. 1, 2) serves as a unique archive for major geobiological changes across the Ediacaran–Cambrian transition (Grotzinger et al., 1995; Laflamme et al., 2013, Darroch et al., 2015; Schiffbauer et al., 2016). The group is a 3000-meter-thick succession of mixed shallow-marine and fluvial, siliciclastic and carbonate rocks. This succession records an interval of time from approximately 550 Ma to 535 Ma. The Nama Group is divided from bottom to top into the Kuibis, Schwarzrand, and Fish River subgroups (Germs, 1972; Geyer, 2005, Grotzinger and Miller, 2008) (Fig. 2). The Ediacaran–Early Cambrian Schwarzrand Subgroup was deposited in a foreland basin in response to crustal loading from thrust sheets as subduction occurred along the Gariep belt and farther north along the Damara belt (Gresse and Germs, 1993; Saylor and Grotzinger, 1996). A thrust belt occurs along the western margin of Nama Group exposures (Grotzinger and Miller, 2008). The Schwarzrand Subgroup consists of mixed siliciclastics and carbonates and has been divided into the the Nudaus, Urusis, and Nomtsas formations. The Nudaus Formation consists of two sequences of shale and sandstone, and has Ediacaran body fossils such as *Pteridinium simplex* and *Rangea schneiderhoehni* (Saylor and Grotzinger, 1996; Grotzinger and Miller, 2008 and references therein). The overlying Urusis Formation contains two carbonate platform sequences represented by the Huns and Spitskop members, which are underlain by shelf sandstone and shale units of the Nasep and Feldschuhhorn members, respectively. The Urusis Formation includes the locally abundant biomineralized fossils *Cloudina* and *Namacalathus* associated with stromatolite pinnacle reefs (Saylor and Grotzinger, 1996), the Ediacaran megafossils *Pteridinium simplex* (Saylor and Grotzinger, 1996) and *Swartpuntia germsi* (Narbonne et al., 1997), and rare animal traces of *Streptichnus narbonnei* (Jensen and Runnegar, 2005) towards the top. Incised valley deposits cut into the top of the Urusis Formation and are filled by shales, sandstones, and olistostroms of the Nomtsas Formation (Saylor and Grotzinger, 1996). This formation also contains the trace fossil *Treptichnus pedum* (Grotzinger and Miller, 2008), indicative for the Phanerozoic. The Urusis-Nomtsas formation boundary is complicated and locally developed as incised valleys, and the boundary interval also has multiple ash beds across the southern part of Namibia (Grotzinger and Miller, 2008). Ash beds were dated so far at 545.1±1 Ma (middle part of the Spitskop Member, upper Ediacaran), 543.3±1 Ma (upper part of the Spitskop Member, upper Ediacaran), and 539.4±1 Ma (base of the Nomtsas Formation, lowermost Cambrian) by U-Pb zircon dating. These datings provide the first robust age control across the Ediacaran–Cambrian boundary interval. Later, these ages became recalculated from the existing data sets to 542.68±2.8 Ma for the middle part of the Spitskop Member, 540.61±0.88 Ma for the upper part of the Spitskop Member, and 538.18±1.24 Ma for the base of the Nomtsas Formation (Bowring et al., 2007; Schmitz, 2012).

New ages were published by Linnemann et al. (2019): In the Swartpunt section, ash beds crop out as 8 to 80 cm thick, whitish-greenish, splintery, silicified, and weathering-resistant layers. U-Pb age determinations were performed applying CA-ID-TIMS to zircons grains, using the EARTHTIME ^{205}Pb-^{233}U-^{235}U tracer solution (ET 535, http://www.earthtime.org). Ash 1, located in unit A, has yielded an age of 540.095±0.099 Ma. Up-section in unit C in ascending stratigraphic order, ashes 2 to 5 have depositional ages of 539.58±0.34 Ma, 539.52±0.14 Ma, 539.64±0.19 Ma, and 538.99±0.21 Ma. In unit G of the lower Nomtsas Formation, the 25 cm thick ash 6 (538.58±0.19 Ma) exhibits features similar to those of older ashes and has been ripped into metre-sized fragments. Due to the wide distribution of related fragments over several 100 meters we assume ash 6 is a primary ash bed in the Nomtsas Formation, which has been fragmented during sediment deposition. Alternatively and less probable, ash 6 could be reworked material from the underlying Spitskop Member. If so, its age of 538.58±0.19 Ma provides a maximum depositional age of the Nomtsas Formation. In any case, this age provides a minimum age for the base of the Cambrian. Even if ash 6 occurred primary in the Spitskop Member, it must be younger than ash 5 (538.99±0.21 Ma) and also younger than the Cambrian fossil-bearing bed in unit F, because no additional ash bed exists between ash 5 and the Cambrian fossil assemblage at meter 127 of the Swartpunt section. It should be noted that another ash bed aged at 538.18±1.11 Ma is reported from unit G in the Nomtsas Formation (Grotzinger et al., 1995).

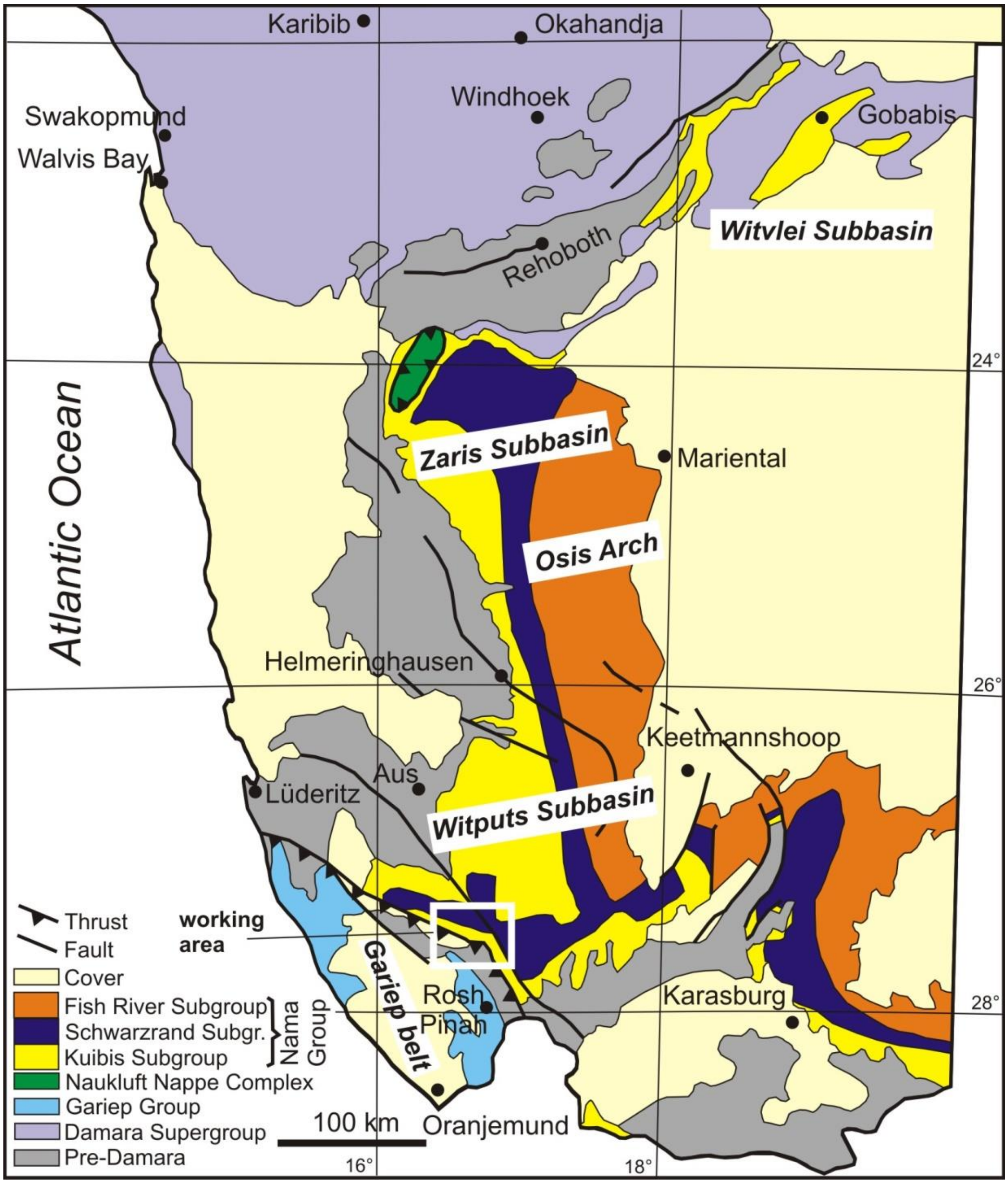

Fig. 1: Geological map of southern Namibia and the Nama basin (Grotzinger and Miller, 2008).

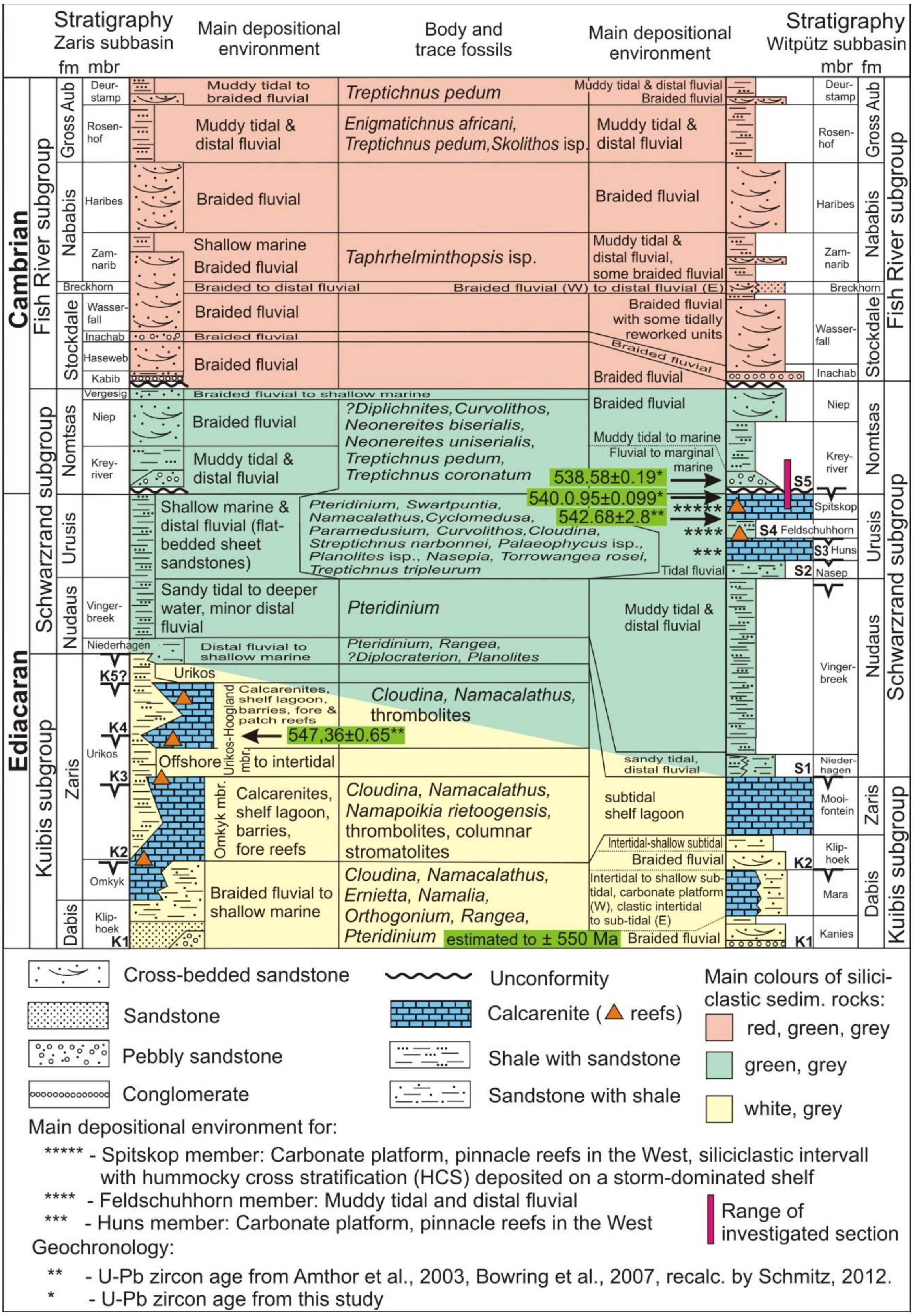

Fig. 2: Comparative stratigraphy of the Nama Group in the Zaris and Witputs subbasins of the Nama basin including main fossils and depositional environments (modified from Grotzinger and Miller, 2008).

The Swartpunt and Swartkloofberg sections are situated on different thrust plates, which originated during the formation of the Gariep belt (Saylor and Grotzinger, 1996). Section units A to F (Farm Swartpunt) occur on the lower thrust plate, whereas unit F (Farm Swartkloofberg) sits on the middle thrust plate (Saylor and Grotzinger, 1996) (Figs. 3 to 5). New documentation of the section in the framework of this study is provided by Figs. 4, 6, and 7. Fossil findings are represented in Fig. 8.

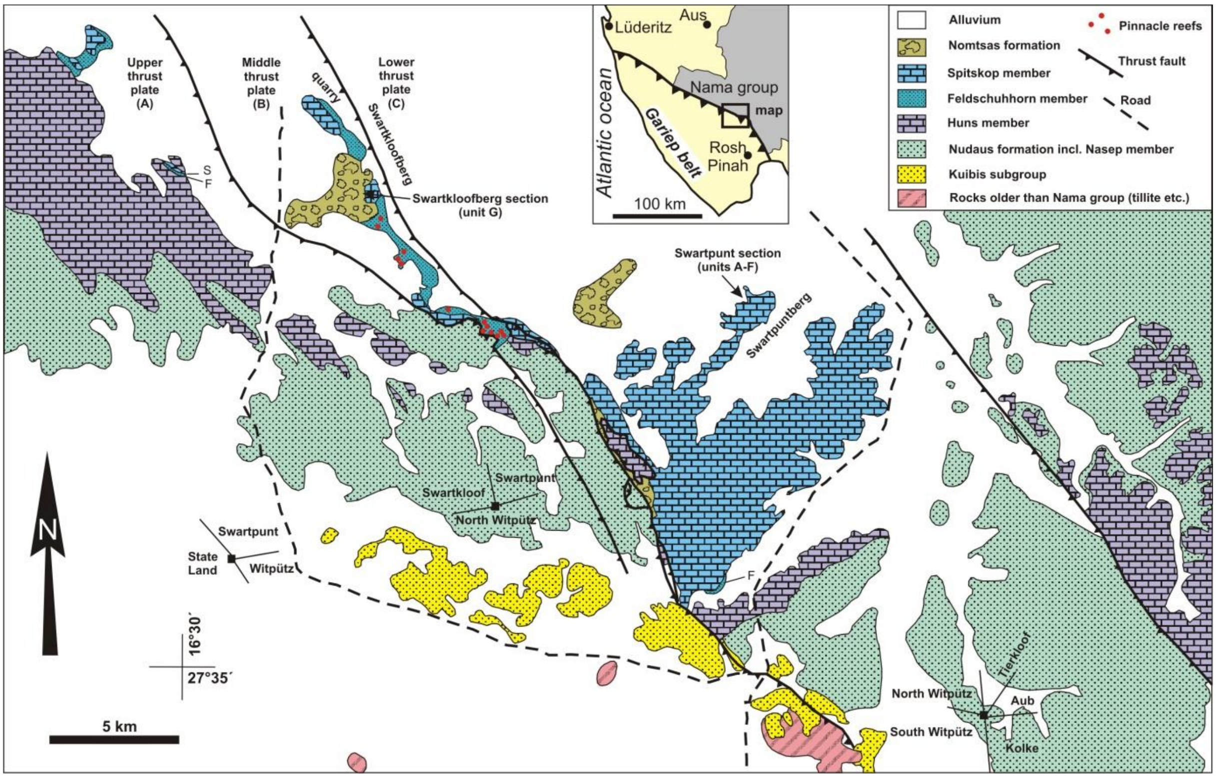

Fig. 3: Geological map of the farms Swartkloof, Swartpunt, and Nord-Witpütz. Inset shows location of the area in southwestern Namibia. Note location of the Swartpunt section (units A–F) and the Swartkloofberg section (unit G) (modified from Saylor and Grotzinger, 1996).

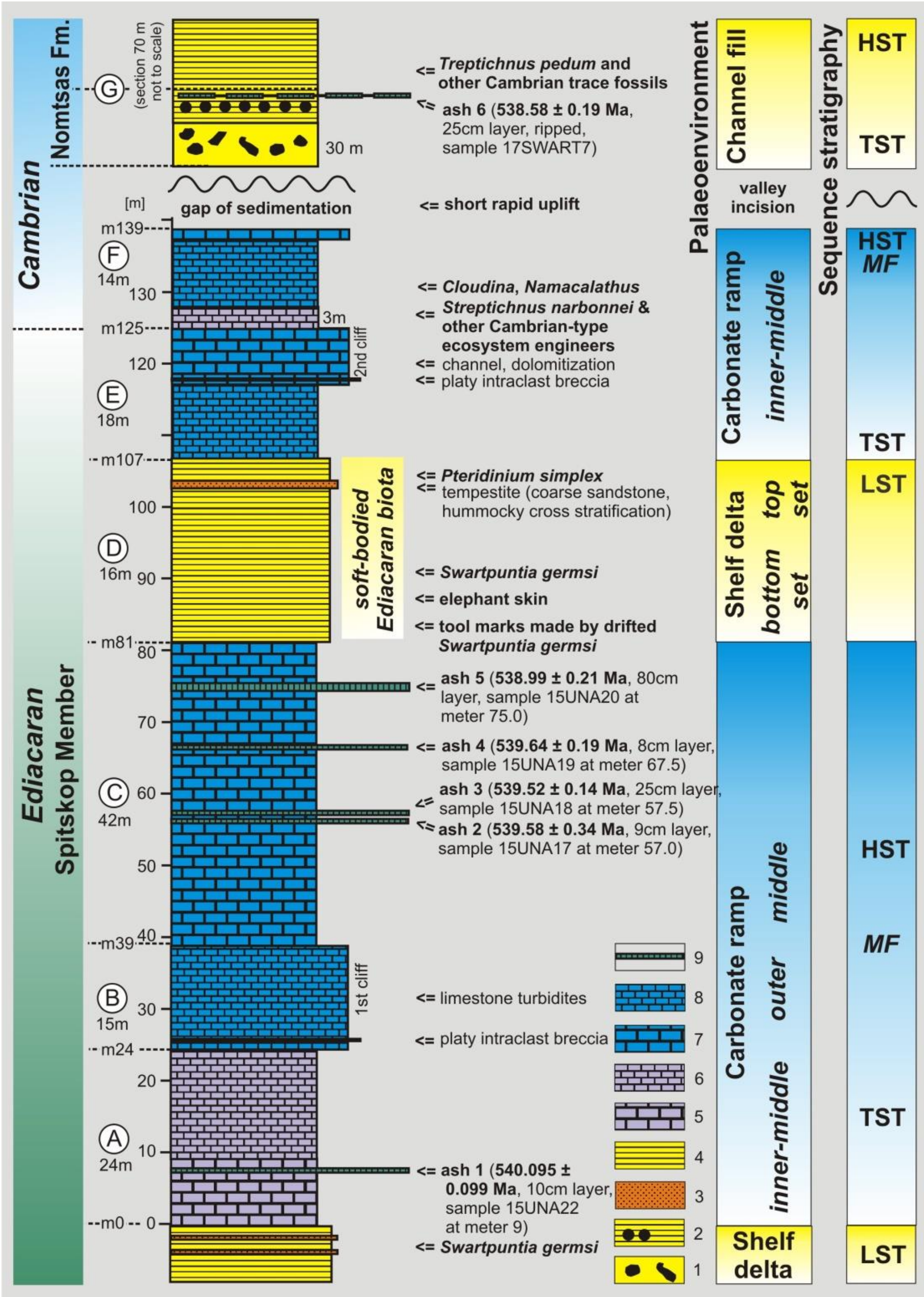

Fig. 4: Complementary geological column of the newly documented sections at Swartpunt (units A-F) and Swartkloofberg (unit G), including high precision geochronological data CA ID TIMS U-Pb zircon ages of ashes 1–6, fossil-bearing strata, lithologies, and information concerning paleoenvironment and sequence stratigraphy. LST – lowstand systems tract, TST – transgression systems tract, HST – highstand systems tract, MF – maximum flooding surface. 1 – debris flow, shale, olistoliths; 2 – shale, sandstone, conglomerate; 3 – grey-green sandstone, 4 – green shale; 5 – grey thick bedded micrite; 6 – grey thin bedded micrite; 7 – black thick bedded micrite; 8 – black thin bedded micrite; 9 – ash bed (tuff) (based on Linnemann et al., 2019)

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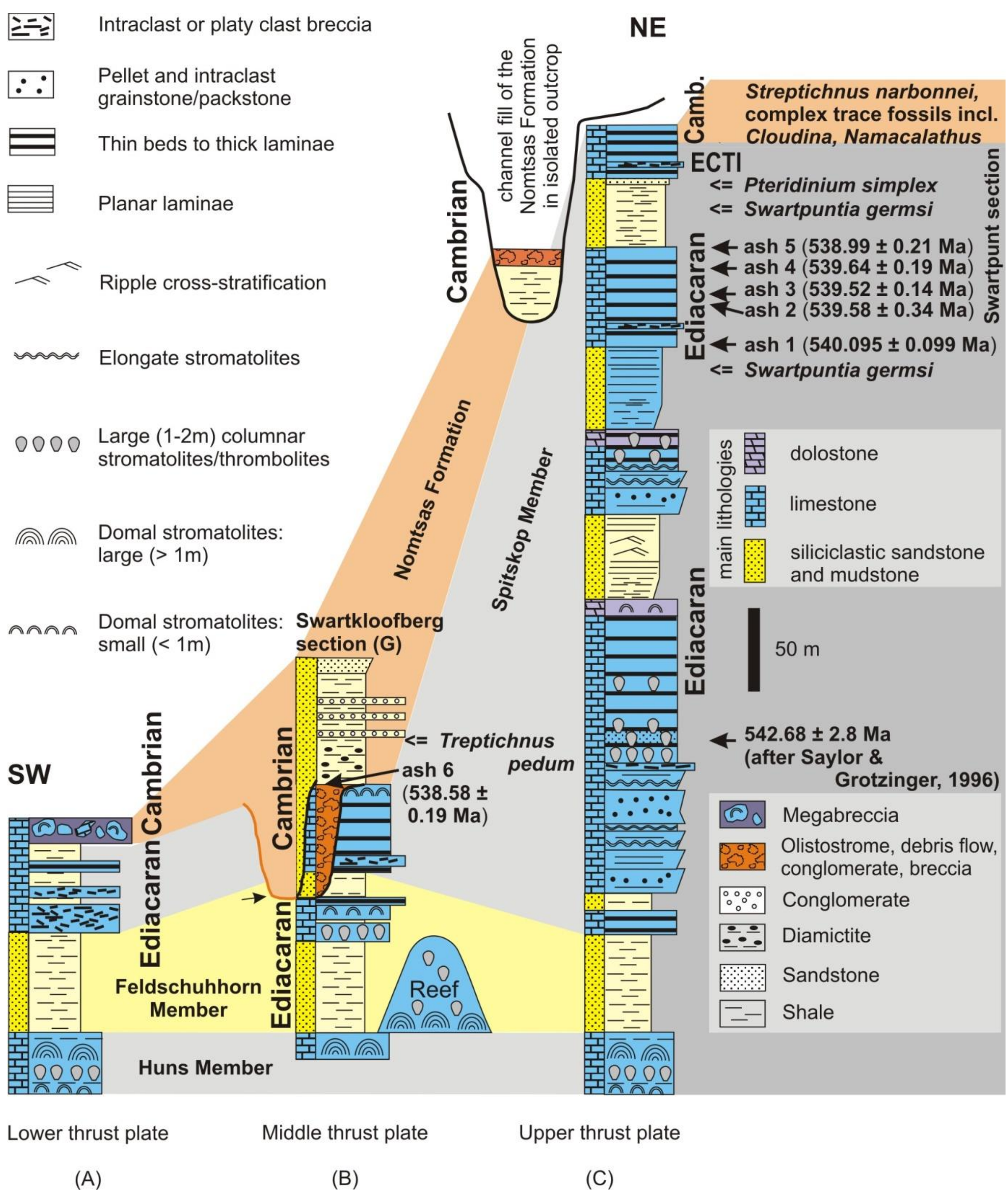

Fig. 5: Sections from the Huns Member up to the Nomtsas Formation for the lower (A), middle (B), and upper trust plates (C) (for locations in the map see SI Fig. 3) (modified after Saylor and Grotzinger, 1996).

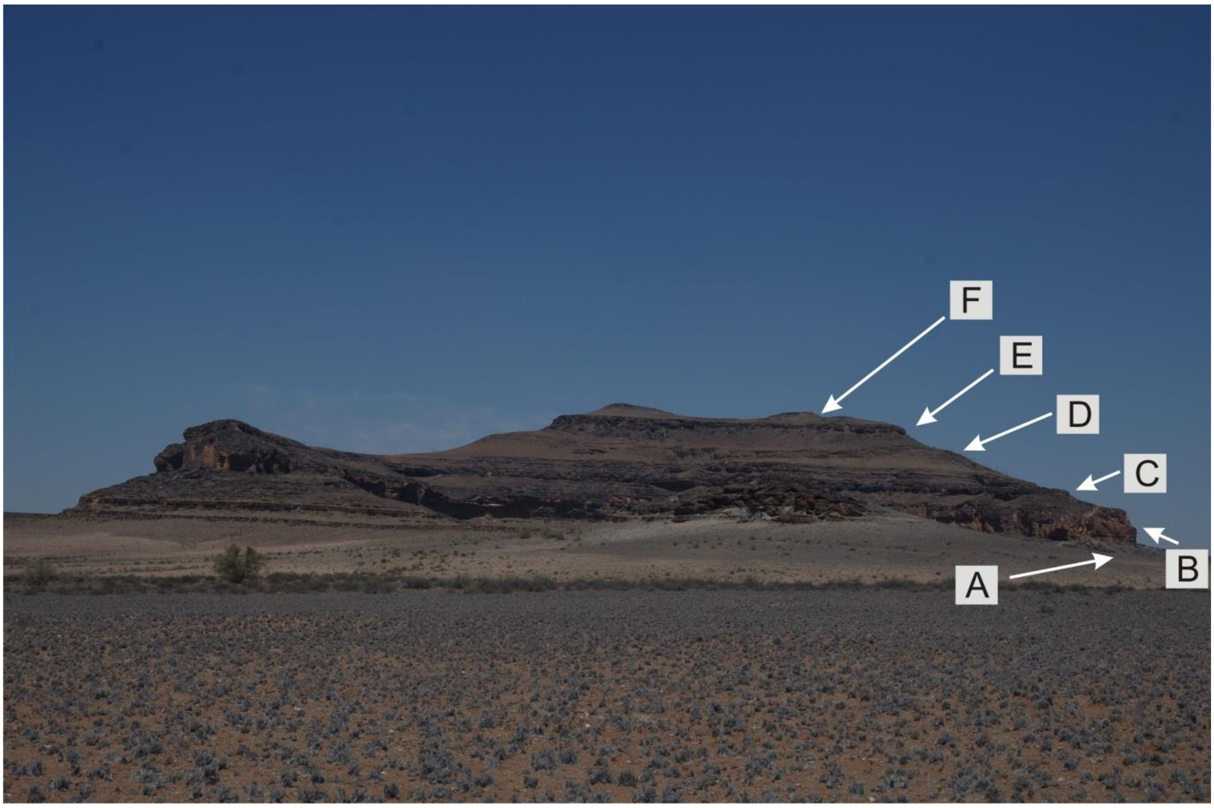

Fig. 6: The Swartpunt section on Farm Swartpunt (Spitskop Member; c. 90 km south of Aus). Lithostratigraphic units of the Spitskop Member indicated (A–F) (Linnemann et al., 2019).

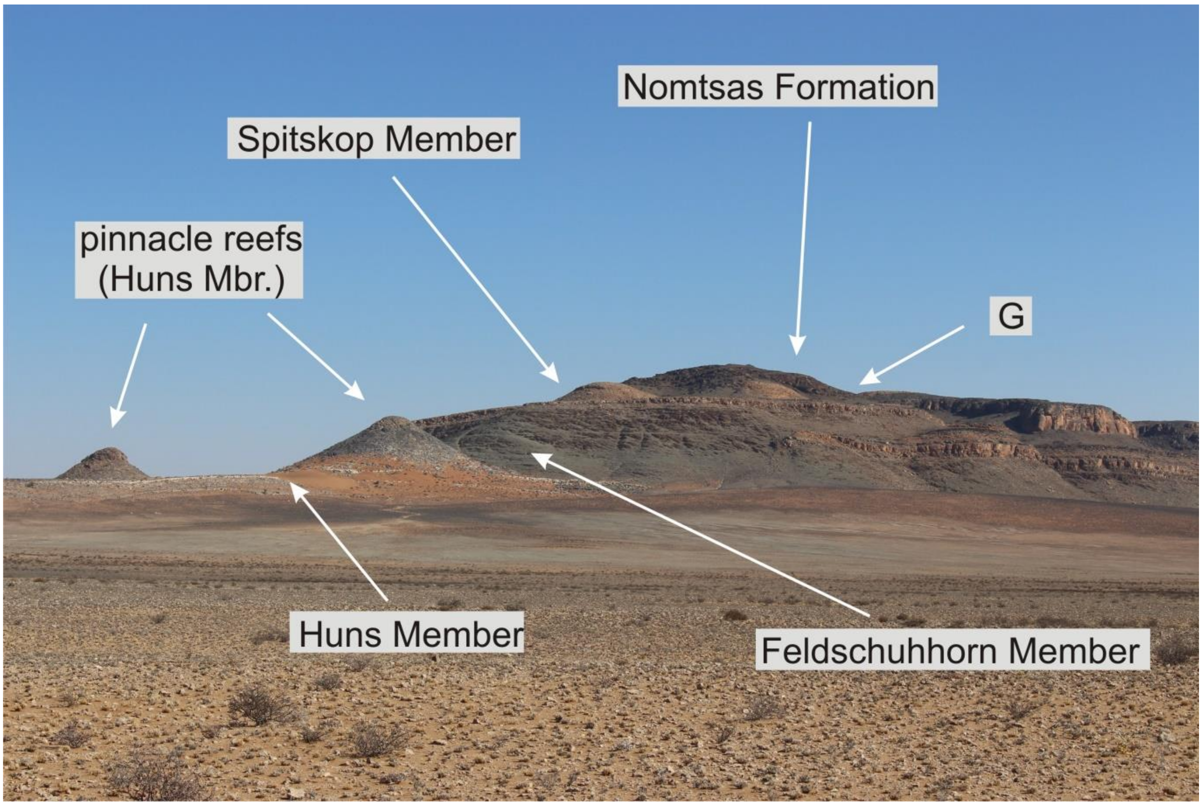

Fig. 7: The Swartkloofberg section on Farm Swartkloof (c. 85 km south of Aus). Position of lithostratigraphic unit G of the Nomtsas Formation indicated (Linnemann et al., 2019).
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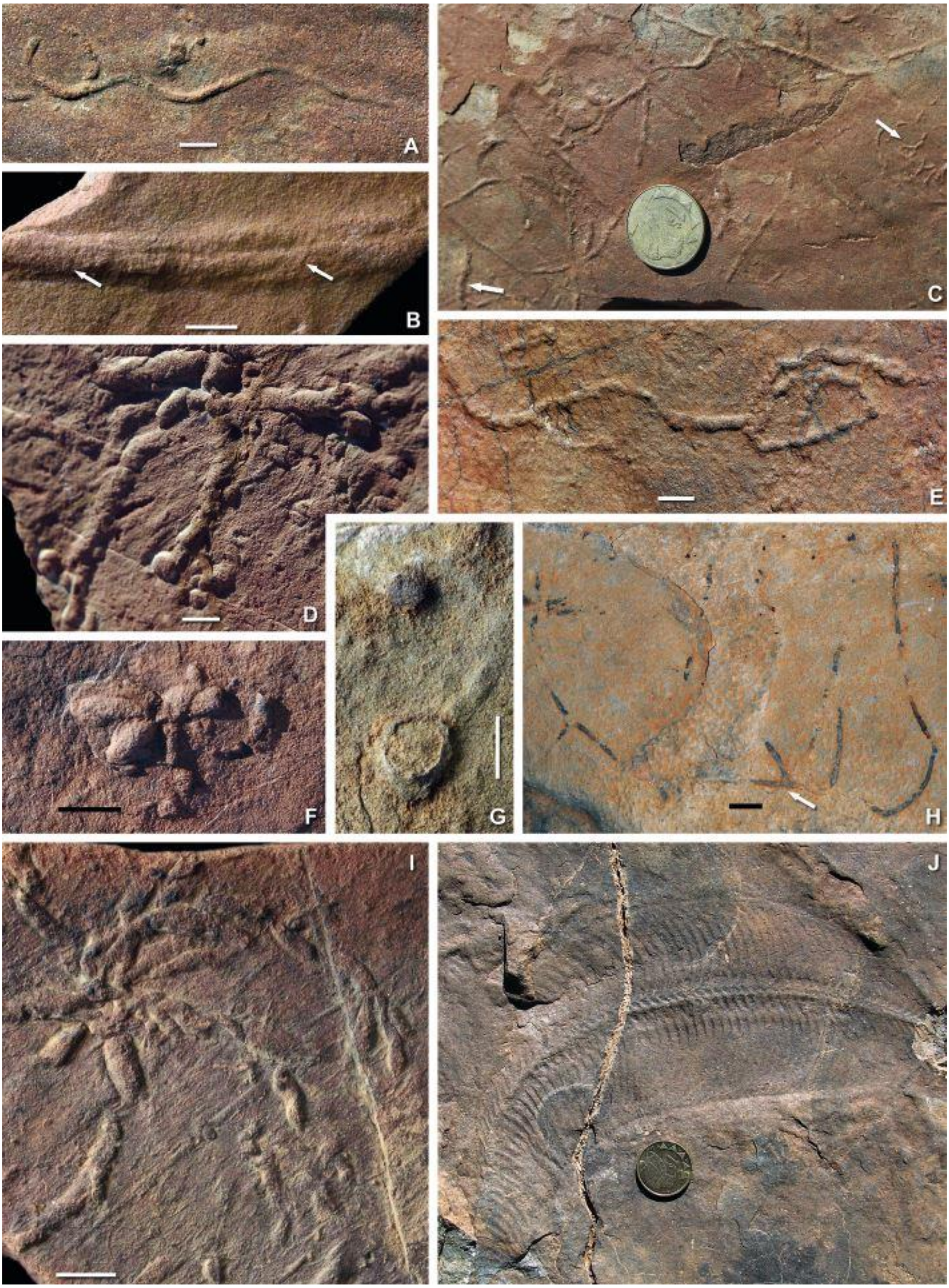

Fig. 8: Fossils from the Swartpunt and Swartkloofberg sections. A – *Cochlichnus* isp.; from Nomtsas Formation, unit G. B – Shallow horizontal burrows resembling *Harlaniella*, with different types of annulations (arrows) suggesting a spiral burrow; Spitskop Member, unit F, metre 127. C – Trace fossil assemblage with simple *Planolites*-type horizontal traces (from Linnemann et al., 2019).

The Port Nolloth zone is the parautochtonous part of the Gariep belt. It includes the Port Nolloth group (Fig. 9), which was deposited on the passive margin of the Kalahari craton. The lower part of the group is characterized by Cryogenian sedimentary deposits (e.g. tillites related to the Snowball Earth (Hofmann et al., 2013, 2014).

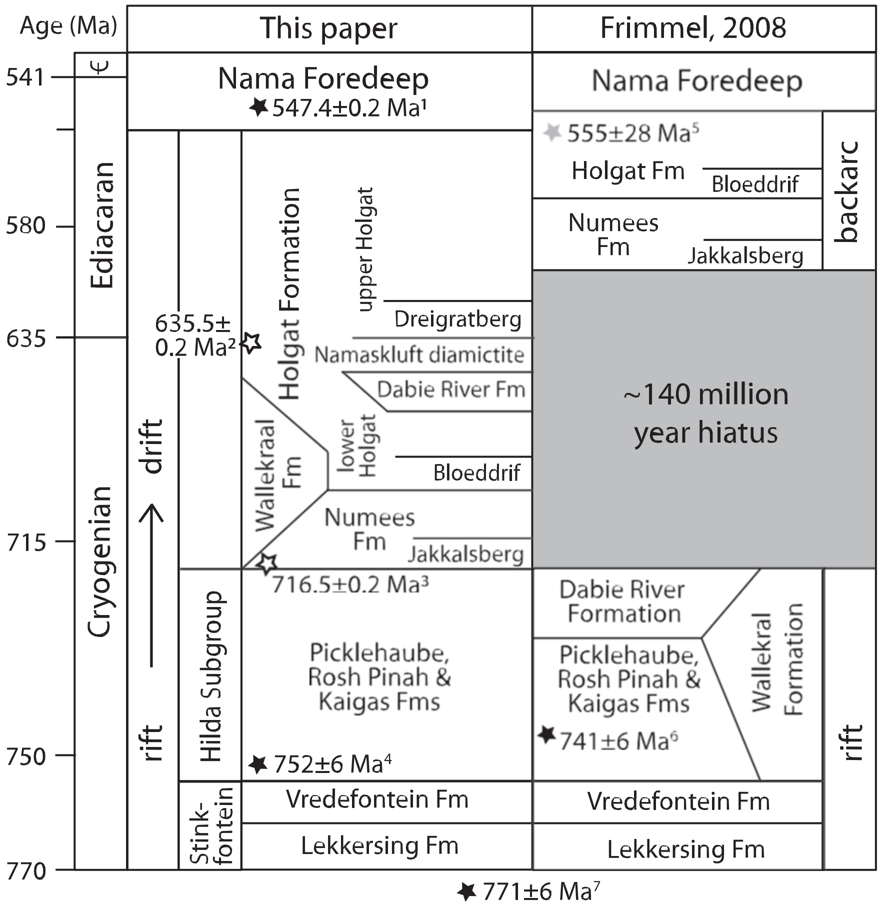

Fig. 9. Generalized stratigraphy of the Port Nolloth Group, contrasting the stratigraphic scheme presented herein with that of Frimmel (2008) (from McDonald et al., 2010).

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Original papers in the Appendix:

March, 5: drive to Aus

Fish River Group: ***Appendix 1_Geyer (2005)***

March, 6: Snowball Earth sediments around Rosh Pina

General geology Gariep belt: ***Appendix 2_McDonald et al. 2010***

Snowball Earth: ***Appendix 3_Hofmann et al. 2013, Appendix 4_Hofmann et al. 2014***

March, 7, 8: Precambrian-Cambrian boundary at farm Swartpunt and incised valleys of the earliest Cambrian at farm Swartkloofberg

Precambrian-Cambrian boundary and incised valleys: ***Appendix 5_Saylor & Grotzinger, 1996; Appendix 6_Linnemann et al., 2019***

C-isotopes: ***Appendix 7_Wood et al. 2015***

March, 9, 10: Ediacaran sediments and fossils at farms Aar and Pockenbank

Ediacaran Fossils: ***Appendix 8_Vickers-Rich et al. 2013, Appendix 9_Vickers-Rich et al. 2016***

Geology: ***Appendix 10_Hall et al. 2013***