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A Systematic Description of the Triassic to Lower Jurassic Section Peak Formation in North Victoria Land (Antarctica)

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Abstract: The Section Peak Formation (Triassic to Lower Jurassic) is an about 200 m thick continental siliciclastic succession overlying metamorphic and igneous basement in southern north Victoria Land, Antarctica. Complete sections are found only in the Deep Freeze Range. In the Eisenhower Range several deca-metres thick conglomerates are overlain by sandstones with minor intercalations of siltstone, claystone and coal. Basal conglomerates in all other areas are thin or absent. Fluvial sandstones dominate throughout most of the Section Peak Formation. In the upper part, sandstone units alternate with fine-grained deposits, which locally contain coal seams. Thin silicic tuff and reworked tuff layers occur in the uppermost part of the Section Peak Formation. The depositional system is interpreted as a large-scale, sand-dominated braid-plain. Pebble composition points to erosion of basement rocks similar to those exposed in north Victoria Land, especially in the Wilson Terrane. The occurrence of quartz-rich sandstone as well as arkosic sandstone and litharenite suggests that the sedimentary basin had several source areas with distinct lithologies. The Section Peak Formation is intruded by sills of the Ferrar Group and overlain by the reworked silicic tuffs of the Shafer Peak Formation, or locally by coarse-grained mafic volcaniclastic deposits. These rocks, formerly described as Exposure Hill Formation, have been recognized as a facies occurring in diatreme structures as well as intercalated in several stratigraphic levels.

Zusammenfassung: Die Section Peak Formation (Trias bis Unterjura) ist eine etwa 200 m mächtige kontinentale, siliziklastische Abfolge über metamorphem und magmatischem Grundgebirge im südlichen Nordviktorialand, Antarktis. Vollständige Profile sind nur in der Deep Freeze Range aufgeschlossen. In der Eisenhower Range werden mehrere Dekameter mächtige Konglomerate von Sandsteinen überlagert, in die Silt- und Tonsteine sowie lokal Kohle eingeschaltet sind. In allen anderen Gebieten sind basale Konglomerate geringmächtig oder fehlen. Der überwiegende Teil der Section Peak Formation wird aus fluviatilen Sandsteinen aufgebaut. Im höheren Teil wechseln Sandsteineinheiten mit feinkörnigen Ablagerungen, die lokal Kohleflöze enthalten. Im höchsten Teil der Section Peak Formation treten geringmächtige felsische Tuffe oder Tuffite auf. Das Ablagerungssystem kann als große, Sand dominierte Zopfstrom-Ebene interpretiert werden. Das Geröllspektrum der Konglomerate ist dem in Nordviktorialand anstehenden Grundgebirge ähnlich, speziell dem im Wilson Terrane. Das Auftreten von sowohl Quarz reichen Sandsteinen als auch Arkosen und Lithareniten spricht für mehrere Liefergebiete mit unterschiedlichen Lithologien. In die Section Peak Formation sind Lagergänge der Ferrar-Gruppe eingedrungen. Die Abfolge wird stratigraphisch von den felsischen Tuffiten der Shafer Peak Formation überlagert, lokal auch von mafischen vulkanoklastischen Ablagerungen. Diese Gesteine, die bisher als Exposure Hill Formation beschrieben wurden, können als Fazies verstanden werden, die sowohl in Diatremstrukturen als auch als Einschaltung in verschiedenen stratigraphischen Niveaus vorkommt.

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INTRODUCTION

In the southern sector of north Victoria Land siliciclastic deposits of Triassic to Early Jurassic age overlie pre-Devonian basement. These undeformed sedimentary rocks are part of the Victoria Group (Beacon Supergroup) and were deposited in a continental sedimentary basin at the Panthalassan margin of Gondwana. They are overlain by volcaniclastic deposits and by the late Early Jurassic Kirkpatrick plateau lava flows (Ferrar Group) that form the prominent, up to 1000 m high cliffs of the Mesa Range. The entire sedimentary succession between the basement and the lava flows is intruded by mafic sills (Ferrar Group), which range in thickness from metre to hundred-metre scale. The sedimentary rocks are well exposed along the escarpment of the Polar Plateau in the Eisenhower and Deep Freeze ranges, and in the upper Rennick Glacier area (Fig. 1). Additional outcrops occur in the Southern Cross Mountains, i.e., east and southeast of the Mesa Range.

Early Mesozoic units in the central Transantarctic Mountains and in south Victoria Land have been studied intensely in the past, and the stratigraphy is well-established (e.g., BALLANCE 1977, MCKELVEY et al. 1977, BARRETT et al. 1986, COLLINSON 1990, ELLIOT & LARSEN 1993, COLLINSON et al. 1994, SIDOR et al. 2008). In contrast, the early Mesozoic sedimentary succession in north Victoria Land is poorly understood mainly for two reasons: (1) Independent studies reported different sedimentary successions from different parts of north Victoria Land, and there is no comprehensive description covering all outcrops. (2) The thickest and most complete sections in the Deep Freeze Range remained virtually unstudied because high altitudes, steep cliffs, and catabatic winds make these outcrops difficult to access. During the German Antarctic North Victoria Land Expedition in 2005/2006 (GANOVEX IX), we studied 22 representative outcrops of the Section Peak Formation, including several long sections in the Deep Freeze Range (Fig. 1, Tab. 1). Fieldwork was carried out jointly by the authors specialized in sedimentology (R. Schöner), palaeobotany (B. Bomfleur), palaeozoology/biofacies (J. Schneider) and igneous petrology (L. Viereck-Götte). Fieldwork was based on day-trips by helicopter from the German Gondwana Station at Terra Nova Bay, and on a three-week field camp at Mount Carson east of the Mesa Range (Camp Carson, Fig. 1). We spent thirty-three days in the field, measured about 550 m of sedimentary sections of the Section Peak Formation on cm/dm-scale, and about 1250 m in total.

This paper provides a systematic description of all sections of the Section Peak Formation studied during GANOVEX IX.

We discuss our new results in the light of previous field investigations and present a revised stratigraphic framework including all current data on early Mesozoic sedimentation in north Victoria Land.

GEOLOGICAL BACKGROUND AND PREVIOUS RESEARCH

The Victoria Group (Beacon Supergroup) in north Victoria Land includes upper Paleozoic deposits north of the Mesa Range and Triassic to Lower Jurassic deposits in the southern part from the Outback Nunataks to the Terra Nova Bay (Ross Sea) area. The sedimentary rocks unconformably overlie the basement, which consolidated during the early Paleozoic Ross Orogeny (e.g., KLEINSCHMIDT & TESSENSOHN 1987, FEDERICO et al. 2006). All known outcrops of the Section Peak Formation are located on the Wilson Terrane, which comprises low- to high-grade metamorphic rocks, and granitoids intruded during the latest Cambrian to Early Ordovician (Granite Harbour intrusives; ENCARNACIÓN & GRUNOW 1996).

Rocks of the Beacon Supergroup in north Victoria Land were discovered by DAVID & PRIESTLEY (1914), and an early Mesozoic age was suggested based on fossil flora from sandstone boulders in glacial moraines on the Priestley Glacier (DEBENHAM 1921). The first systematic investigations were carried out in the early 1960s. GAIR (1964) described thin sandstone units between the basement and mafic Ferrar rocks in the upper Rennick Glacier area. RICKER (1964) observed pebbly arkosic sandstones and conglomerates as well as quartz sandstones and siltstones in the southern Eisenhower Range resting on weathered granitic basement. He also mentioned coaly deposits and silicified wood fragments at Timber Peak. Based on micro- and macroflora data from Timber Peak and Section Peak, the age of these deposits has been given as Middle to Late Triassic and possibly Early Jurassic (GAIR et al. 1965, NORRIS 1965). In contrast, field investigations between Mawson and Priestley Glacier led SKINNER & RICKER (1968) to conclude that the sedimentary deposits interfinger with lava flows and thus must be Early to Middle Jurassic in age. A comprehensive description of the Beacon Supergroup between the Outback Nunataks and Vantage Hills has been given by COLLINSON & KEMP (1983) and COLLINSON et al. (1986), who introduced the name Section Peak Formation for the Upper Triassic (to Lower Jurassic?) deposits, and interpreted them as sandy braided stream deposits. The type section is a 42 m thick sandstone unit at Section Peak in the Lichen Hills. The presence of the Triassic seed fern *Dicroidium odontopteroides* at Vulcan Hills has lent further support for a Triassic age of the

Area	Outcrop	Coordinates		Section Peak Format.		Base	Top
		South	East	Elevation above s.l. (m)	c. thickness (m)		
Eisenhower Range	Thern Promontory	74°34'	162°00'	1510 [b]	50	Granite	Sill
	Anderton Glacier	74°35'	162°15'	1820 [b]	80	Granite	Sill
	Eisenhower Range Cliff	74°28'	162°31'	2275 [b]	45	Schists	Sill
	Skinner Ridge	74°22'	161°51'	2005 [b]	25	Ferrar sill	Sill
	Timber Peak	74°11'	162°23'	2840 [b]	180	Schists	Sill
Deep Freeze Range	Priestley Glacier	74°01'	162°27'	*c*. 2800 [t]	200	Schists	Volcaniclastics
	Shafer Peak S Ridge	74°02'	162°37'	*c*. 3000 [b]	40	Granite	Sill
	Shafer Peak N Ridge	74°00'	162°36'	*c*. 3100 [b]	60	-	Volcaniclastics
	Point 3350	73°58'	162°58'	*c*. 2615 [b]	60	Granite	Volcaniclastics
	Mt. Adamson	73°56'	163°00'	*c*. 2700 [b]	170	Granite	Volcaniclastics
	Archambault N' Plateau	73°41'	162°36'	*c*. 2800 [b]	85	Granite	Sill
	Archambault Ridge	73°41'	162°45'	2670 [t]	70	Granite	Sill
Upper Rennick Glacier area	Exposure Hill Plateau	73°32'	162°41'	2640 [b]	25	Sill	-
	Section Peak Cliff	73°14'	161°56'	*c*. 2250 [b]	25	Granite	Sill
	Section Peak Plateau	73°14'	161°55'	2400 [b]	23	Sill	Sill
	Barren Bluff	73°04'	161°17'	*c*. 2100 [b]	15	Schists	Sill
	Myosotis Nunatak	73°01'	161°30'	1960 [b]	15	Sill	Sill
	Johannessen Nunatak	72°52'	161°08'	1900 [b]	15	Sill	Sill
	Roberts Butte	72°39'	160°08'	*c*. 2800 [b]	25	Granite	Sill
Southern Cross Mountains	Vulcan Hills	73°40'	163°37'	*c*. 2750 [b]	180	Granite	Sill
	Chisholm Hills West Rg.	73°27'	163°19'	2525 [b]	70	Sill	Sill
	Stewart Heights	73°29'	163°55'	2650 [b]	15	Granite	Sill
	Runanway Hills West	73°18'	163°28'	*c*. 2200 [b]	20	Sill	Sill

Tab. 1: Localities with exposed Section Peak Formation in north Victoria Land investigated during GANOVEX IX. GPS-coordinates are helicopter landing sites and based on the world geodetic system (WGS) 84. Elevations indicated with "*c*." are approximations that were supplemented from the 1:250,000 topographic maps of the U.S. Geological Survey. Approximate thickness of the Section Peak Formation is the cumulative stratigraphic thickness of sedimentary rocks separated by sills and includes parts of the sections covered by snow, ice and/or talus. All values from outcrops capped by Ferrar sills are minimum thicknesses of incomplete sections. [b] = base of section; [t] = top of section.

Tab. 1: Lokalitäten der Section Peak Formation in Nord-Viktorialand, die während GANOVEX IX untersucht wurden. Die GPS-Koordinaten repräsentieren die Helikopter-Landepunkte und sind auf das WGS (world geodetic system) 84 referenziert. Mit "*c*." markierte Höhenangaben sind aus den topographischen Karten 1:250,000 des U.S. Geological Survey abgegriffene Näherungswerte. Die angegebenen Mächtigkeiten der Section Peak Formation sind kumulative stratigraphische Mächtigkeit der Sedimente (ohne Lagergänge). Sie schließen auch Abschnitte ein, die mit Schnee, Eis oder Schutt bedeckt waren. Alle Mächtigkeitsangaben von Aufschlüssen mit Ferrar-Lagergängen am Top stellen Mindestmächtigkeiten unvollständiger Profile dar. [b] = Profilbasis, [t] = Profiltop.

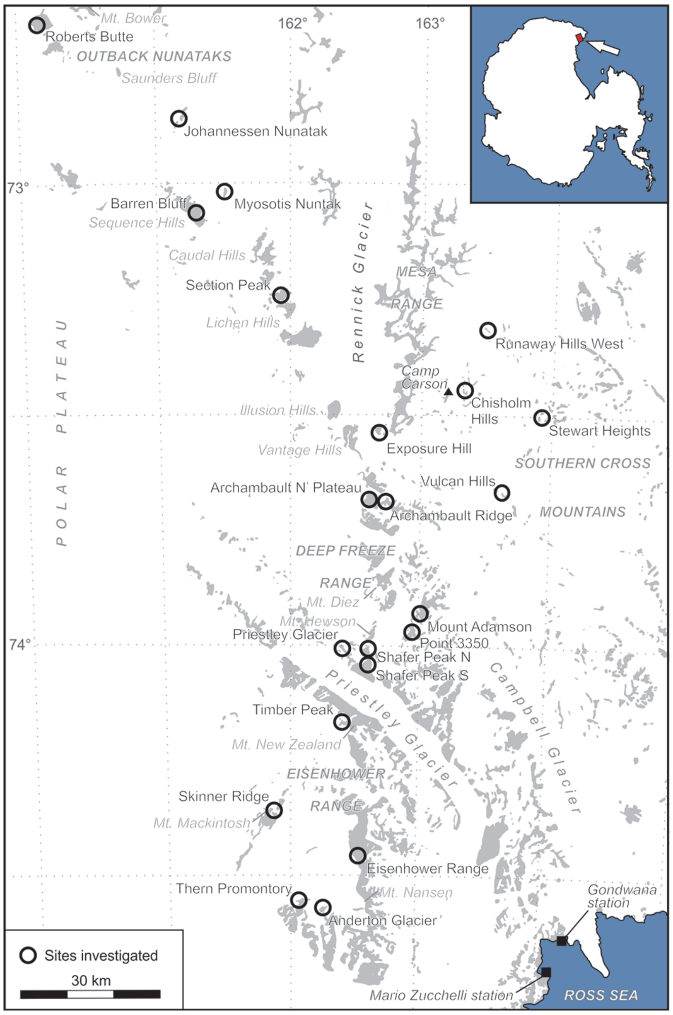


Fig. 1: Map of southern north Victoria Land showing the localities of the Section Peak Formation investigated during GANOVEX IX (2005/2006).

Abb. 1: Karte von Nordviktorialand mit den Lokalitäten der Section Peak Formation, die während GANOVEX IX (2005/2006) untersucht wurden.

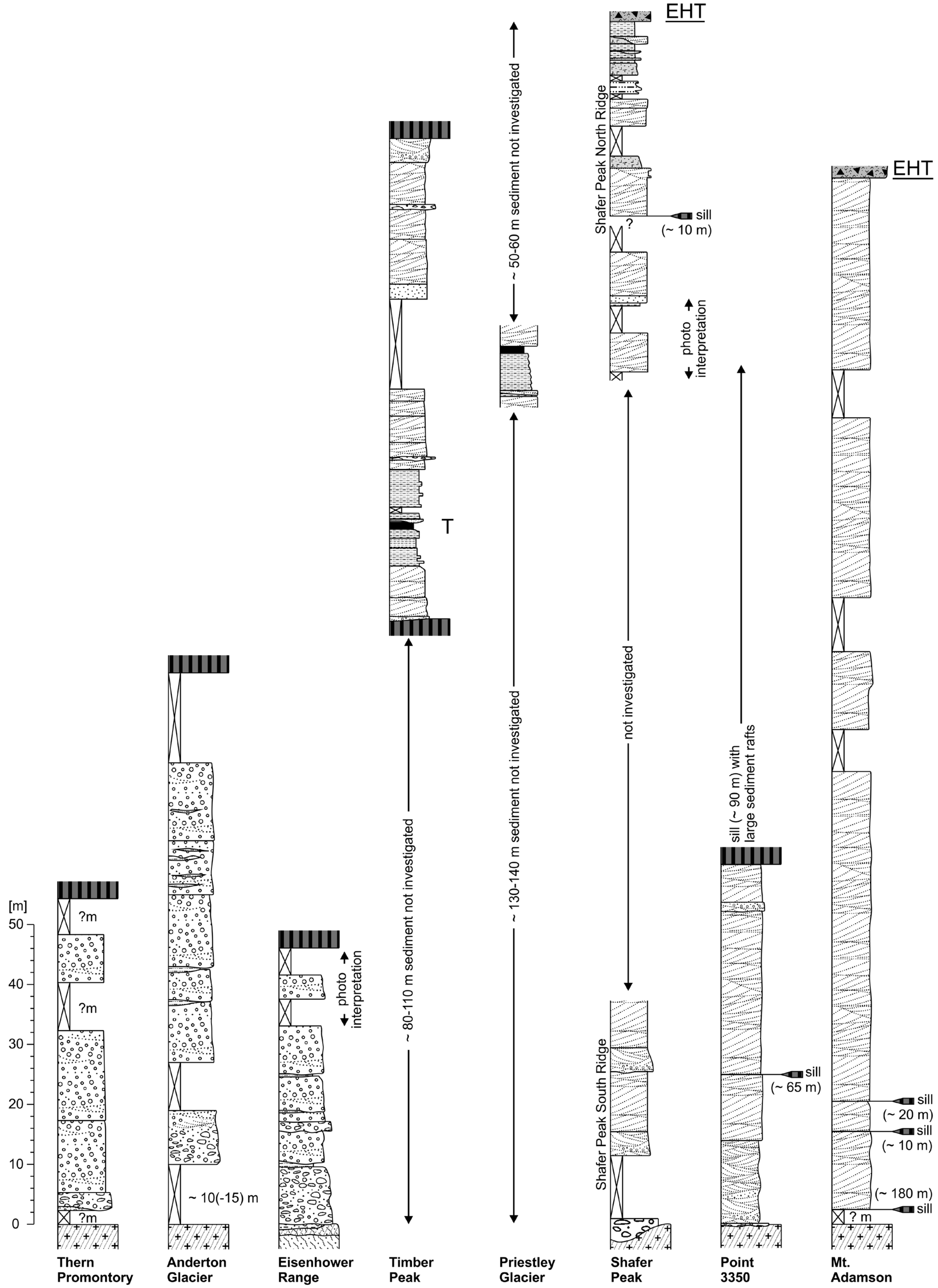
formation (Tessensohn & Mädler 1987). Roland et al. (1989) described thin sandstones on top of granite from the Outback Nunataks containing detrital charcoal, and noted the intrusive character of the capping Ferrar dolerite. Di Giulio et al. (1997) and Casnedi & Di Giulio (1999) studied the sedimentology and petrography of five sections in the Eisenhower and Deep Freeze ranges. They proposed that basaltic lava flows were interbedded with the sandstones of the Section Peak Formation to explain the abundant volcanic grains in the sandstones. Based on these assumptions and outdated radiometric data (Brotzu et al. 1988), they suggested a Middle Jurassic age for the entire Section Peak Formation. However, recent radiometric ages of the Ferrar yield 183-184 Ma, a late Early Jurassic age (Encarnación et al. 1996). Pertusati et al. (2006) re-investigated the carbonaceous horizons at Section Peak already studied by Norris (1965) and suggested that the palynoflora confirms an Early Jurassic age for the upper part of the Section Peak Formation. Goodge & Fanning (2010) measured U-Pb ages of detrital zircons of a sample from the type locality of the Section Peak Formation. The youngest populations indicate a maximum depositional age of 191 ±4 Ma, i.e., Early Jurassic. Considering these contradictory observations and conclusions, the field work during GANOVEX IX focused on a systematic re-evaluation of previously described outcrops, and on searching and studying new outcrops in areas that were not visited before.

NEW STRATIGRAPHIC FRAMEWORK

Our investigations show that the Triassic-Jurassic sedimentary succession can be subdivided into two stratigraphic formations and intercalated products of local explosive volcanism (Fig. 3). The lower stratigraphic unit is the Section Peak Formation. Based on the original definition of Collinson et al. (1986), the name Section Peak Formation is expanded for all continental siliciclastic sandstone deposits and interbedded conglomerate, pelite and coal observed in the area in between the Outback Nunataks and the Terra Nova Bay (Ross Sea). The Section Peak Formation is overlain by the Shafer Peak Formation (Schöner et al. 2007), a homogeneous fine-grained unit of reworked tuffs that contains abundant silicic shards. According to macrofloral and palynological evidence, the Triassic-Jurassic boundary is supposed to lie within the Section Peak Formation (see Norris 1965, Pertusati et al. 2006, Bomfleur et al. 2007), but detrital zircon ages suggest that the entire Section Peak Formation could be Early Jurassic in places (Goodge & Fanning 2010). Clastic products of mafic volcanic eruptions, formerly described as a separate stratigraphic formation (Exposure Hill Formation of Elliot et al. 1986), occur within local diatreme structures as well as intercalated in different stratigraphic levels of the sedimentary succession (Fig. 3). The predominantly hydroclastic eruptions are the first subaerial expression of Ferrar magmatism, and are related to shallow sill emplacement into wet sediments (Viereck-Goette et al. 2007). The first local pillow lavas and lava flows are in places overlain by sedimentary rocks including fossiliferous lake deposits. Only the subsequent volcanic eruptions produced the thick, homogeneous Kirkpatrick plateau-lava succession (Ferrar Group) that virtually covered the entire landscape.

OUTCROP DESCRIPTION

Coordinates and elevations of the outcrops described here, and exposed stratigraphic thickness as well as base and top of the Section Peak Formation are listed in Table 1. Simplified lithological columns of the measured sections are given in Figure 2. In the Eisenhower Range, the Section Peak Formation is exposed along the steep cliff running from Thern Promontory to Mount Nansen and Mount New Zealand, as well as at Skinner Ridge and Timber Peak. In the Deep Freeze Range, almost continuous sections are exposed along the cliff north of the upper Priestley Glacier, at Shafer Peak, at Mount Hewson, at Mount Adamson, and along the cliff running north from Mount Dietz to Archambault Ridge. The Section Peak Formation can be further traced along the chain of “hills” bordering the Polar Plateau from the Vantage Hills to the Sequence Hills, and further north at Myosotis and Johannessen Nunatak, at Saunders Bluff, Mount Bowers and Roberts Butte. Further east, good outcrops occur at Vulcan Hills, in the vicinity of Exposure Hill, in the Chisholm Hills area, at Runaway Hills, and at Stewart Heights (Fig. 1).



EHT
EHT
[m]
50
40
30
20
10
0
?m
?m
?m
~ 10(-15) m
photo interpretation
~ 80-110 m sediment not investigated
T
~ 50-60 m sediment not investigated
~ 130-140 m sediment not investigated
Shafer Peak North Ridge
?
sill (~ 10 m)
photo interpretation
not investigated
Shafer Peak South Ridge
sill (~ 90 m) with large sediment rafts
sill (~ 65 m)
sill (~ 20 m)
sill (~ 10 m)
(~ 180 m)
sill
? m
Thern Promontory
Anderton Glacier
Eisenhower Range
Timber Peak
Priestley Glacier
Shafer Peak
Point 3350
Mt. Adamson

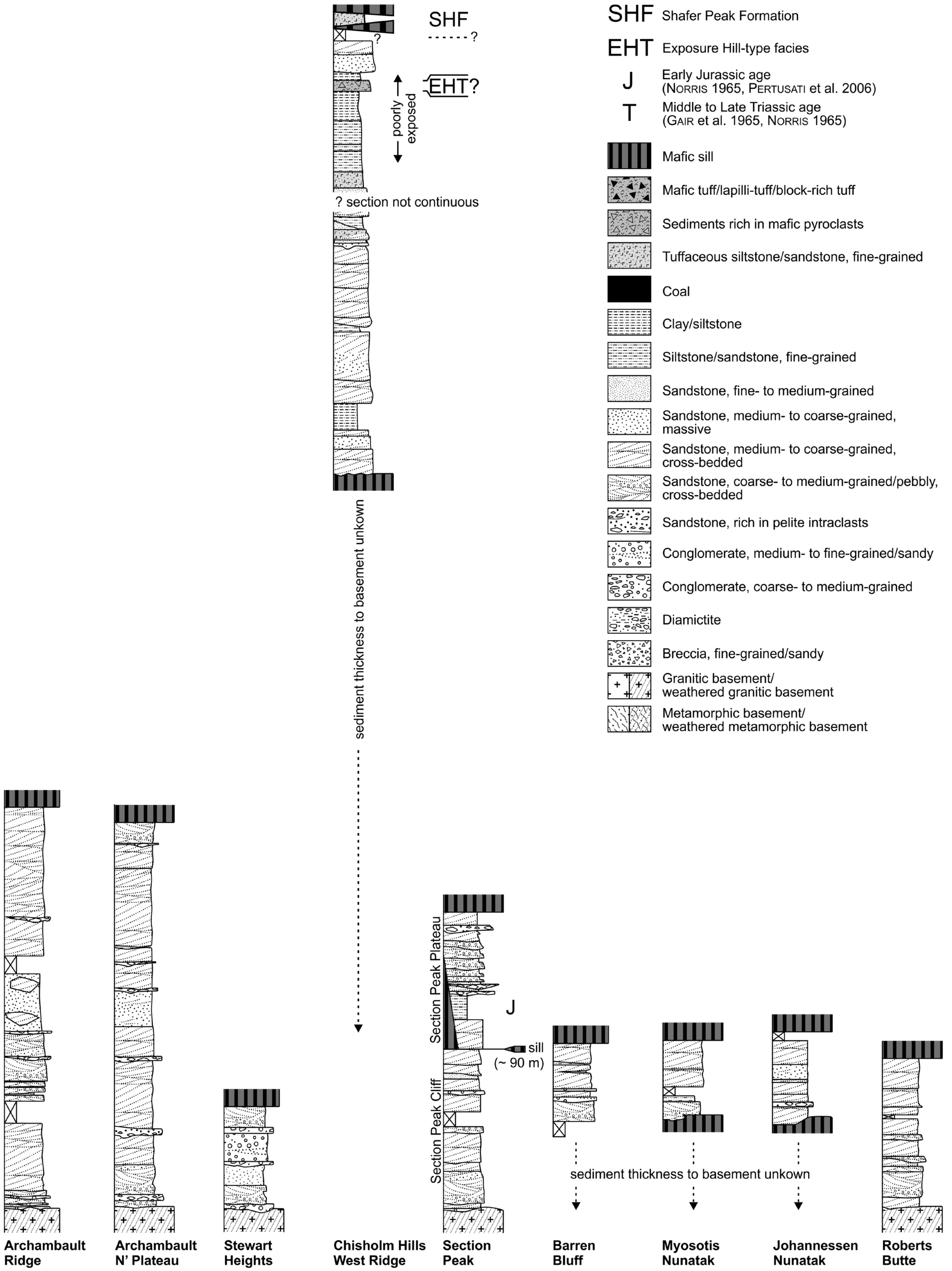


Fig. 2: Sedimentary sections of the Section Peak Formation in southern north Victoria Land; sills are not drawn to scale. The thickest sections are exposed in the northern Eisenhower Range and in the Deep Freeze Range. Lithostratigraphic correlation of the sections is not possible according to present knowledge.

Abb. 2: Sedimentprofile der Section Peak Formation im südlichen Nordviktorialand; die Lagergänge sind nicht maßstäblich dargestellt. Die mächtigsten Profile sind in der nördlichen Eisenhower Range und in der Deep Freeze Range aufgeschlossen. Nach derzeitigem Kenntnisstand können die Profile lithostratigraphisch nicht korreliert werden.

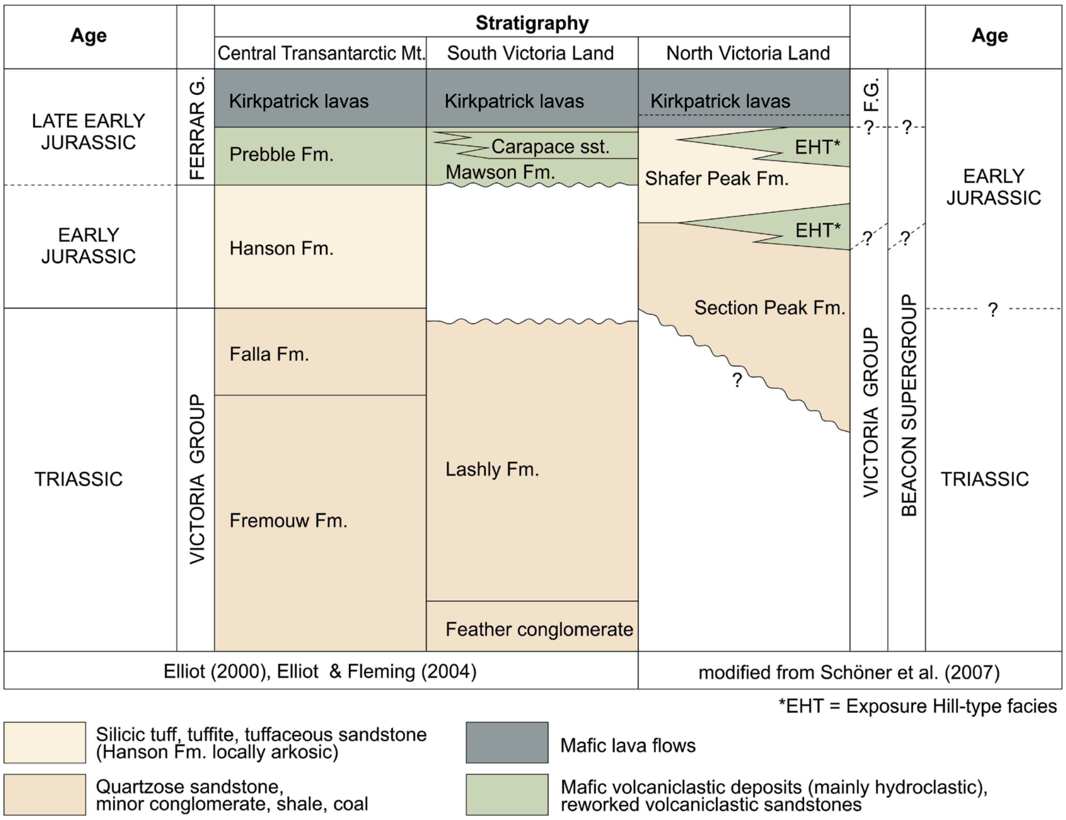


Fig. 3: Stratigraphy of the Triassic to Lower Jurassic deposits in the Transantarctic Mountains. The stratigraphy of north Victoria Land has been revised based on the fieldwork during expedition GANOVEX IX.

Abb. 3: Stratigraphie der triassischen und unterjurassischen Ablagerungen im Transantarktischen Gebirge. Die Stratigraphie von Nordviktorialand wurde auf Grundlage der Geländearbeiten während GANOVEX IX revidiert.

Thern Promontory

The outcrop is a flat ridge west-southwest of the steep promontory that is made up of a Ferrar sill, which can be traced almost continuously along the cliff from Thern Promontory to Mount Nansen and Mount New Zealand. The exposed thickness of this sill ranges from <100 m to >300 m. The lowermost sedimentary rock exposed at Thern Promontory is an arkosic grit, a typical weathering product of granitic rocks. Although the basement is not exposed directly at the ridge, it crops out several hundred metres further to the south and east. The grit is overlain by about 3 m of coarse-grained conglomerate containing well-rounded, partly imbricated pebbles of quartz, whitish felsic igneous rocks (kaolinized rhyolite or aplite?), quartzite/quartzitic sandstone, cm-sized feldspars, biotite granite, grey to black slate, quartz-mica-schist and gneiss (Fig. 4a). The largest cobbles reach diameters of 15 cm. The overlying deposits are composed of alternating medium- to coarse-grained conglomerate and fine-grained, sandy conglomerate, both predominantly trough cross-bedded. The section is not continuously exposed due to snow and ice cover, but is considered at least 50 m thick.

Anderton Glacier

Another large exposure of coarse-grained clastic sedimentary rocks is between the granite and the cliff-forming Ferrar sill east of the upper end of Anderton Glacier, at the foot of a southward promontory of the major escarpment. The contact between the sedimentary sequence and the basement is not exposed, but the top of the granite forms a plateau at about 1820 m. The sedimentary rocks consist of medium- and fine-grained, well- to moderately-sorted conglomerate with subordinate proportions of coarse-grained conglomerate and pebbly sandstone. Sharp vertical and lateral grain-size changes of trough cross-bedded units are common at intervals of a few decimetres to metres (Fig. 4b). Clast imbrication in the most coarse-grained layers suggests transport toward the northwest and northeast/east. Some 5-10 m thick units vaguely suggest a fining-up trend. Interbedded lenticular bodies of fine-grained, silty, grey sandstone are up to 1.2 m thick, typically have a lateral extension of several metres and contain mm- to cm-sized, mostly rectangular fragments of coalified plant axes (Bomfleur et al. 2011 this vol.). The fine- to medium-grained conglomerate is dominated by well-rounded quartz pebbles and whitish sub-rounded to sub-angular alkali feldspar grains

Fig. 4: Conglomerates of the Section Peak Formation in the Eisenhower Range. (a) Base of the section at Thern Promontory. Coarse-grained polymict conglomerate with large granitic cobbles (arrow) above arkosic grit (G). Length of hammer 28.5 cm. (b) Upper part of the section at Anderton Glacier. Cross-bedded, fine-grained fluvial conglomerate with abundant sub-angular white feldspar clasts and coarse-grained sandstone, interbedded with fine-grained, silty sandstone. Note the sharp grain-size changes, and the irregular base and erosive top of the fine-grained unit (arrows), which thins out towards the left margin of the photo. Length of hammer 43 cm. (c) Basal conglomerate above metamorphic basement rocks and a thin layer of diamictite (D) at Eisenhower Range. The erosive base of the coarse-grained fluvial conglomerate and the erosive base of a second coarse-grained unit are marked by arrows. The cliff shown here is about 35 m thick. Brownish rocks forming the cliff in the upper part of the photo are a thick Ferrar sill (S). (d) Detail of (c), showing the base of the fluvial conglomerate (arrow) above poorly sorted clast-rich mudstones (diamictite, D), which are poorly stratified in the upper part, and locally show diffuse stratification and soft sediment deformation in the lower part [brace]. The clast lithologies of the diamictite are identical to those of the underlying metamorphic basement. Length of folding rule 1 m. (e) Dark-grey to black, carbonaceous lacustrine pelite filling a cut-off channel within cross-bedded fluvial sandstones at Skinner Ridge. The top of the pelite has been eroded; the lower part of the overlying channel sandstone contains abundant large angluar pelite intraclasts. Folding rule in the middle of the image 20 cm. (f) Gravel lag deposit at the erosive base of a fluvial sandstone channel unit (arrow) at Skinner Ridge. The lag deposit contains mainly (sub-)angular quartz clasts and grey to black, partly laminated lacustrine pelite intraclasts. Length of hammer 28.5 cm.

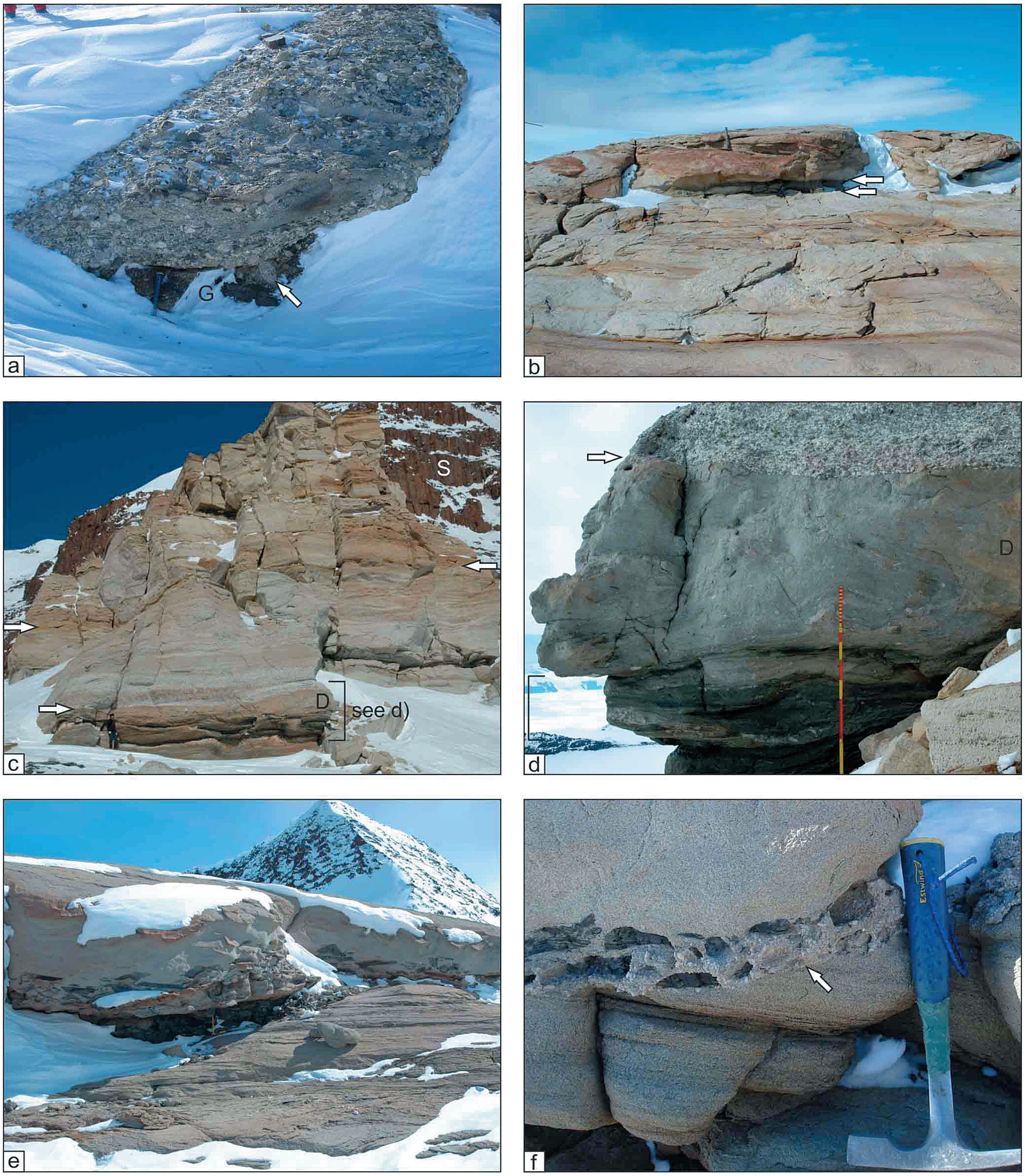


Abb. 4: Konglomerate der Section Peak Formation in der Eisenhower Range. (a) Basis des Profils am Thern Promontory. Grobes polymiktes Konglomerat mit großen Granitgeröllen (Pfeil) über Granitgrus (G). Länge des Hammers 28.5 cm. (b) Oberer Abschnitt des Profils am Anderton Glacier. Schräggeschichtetes, feinkörniges fluviatiles Konglomerat mit zahlreichen kantengerundeten weißen Feldspatklasten und grobkörniger Sandstein; zwischengeschaltet feinkörniger, schluffiger Sandstein. Man beachte die abrupten Korngrößenwechsel sowie die unregelmäßige Basis und die erosive Obergrenze der feinkörnigen Einheit (Pfeile), die nach links auskeilt. Länge des Hammers 43 cm. (c) Basales Konglomerat über metamorphem Grundgebirge und einer geringmächtigen diamiktischen Einheit (D) am Profil Eisenhower Range. Die erosiven Basen des grobkörnigen fluviatilen Konglomerats und einer weiteren grobkörnigen Einheit sind mit Pfeilen markiert. Die hier gezeigte Steilstufe ist etwa 35 m mächtig. Die bräunlichen, Wand bildenden Gesteine im oberen Teil des Bildes gehören zu einem mächtigen Lagergang (S). (d) Detail aus Bild (c). Basis des fluviatilen Konglomerats (Pfeil) oberhalb des schlecht sortierten Klast reichen Tonsiltsteins (Diamiktit, D) mit undeutlicher Stratifizierung im oberen Teil und lokal diffuser bis deformierter Schichtung im unteren Teil [Klammer]. Die Lithologien der Klasten im Diamiktit entsprechen denen im unterlagernden Grundgebirge. Länge des Meterstabes 1 m. (e) Mit dunkelgrauem bis schwarzem, kohligem, lakustrinen Pelit verfüllte, abgeschnittene Rinne innerhalb einer Abfolge fluviatiler Sandsteine am Skinner Ridge. Der Top der feinkörnigen Einheit wurde erodiert; im tieferen Teil des überlagernden Sandsteins sind zahlreiche umgelagerte Intraklasten enthalten. Meterstab in Bildmitte 20 cm. (f) Rückstandssediment an der erosiven Basis einer fluviatilen Rinne (Pfeil) mit (Kanten) gerundeten Quarzklasten und grau-schwarzen, z.T. laminierten Pelit-Intraklasten am Skinner Ridge. Länge des Hammers 28.5 cm.

or alkali feldspar-rich granitic rock fragments. The latter are locally abundant (>50 %), giving the rock a whitish appearance. In addition to the pebble types already described for Thern Promontory, tourmaline-bearing granite pegmatites, dark-grey chert clasts, and sub-rounded fine-grained sand- to siltstone intraclasts up to 20 cm size were observed. The exposed section is about 70 m thick, but base and top are covered by snow, ice and talus; we estimate the total thickness to be between 80-90 m.

Eisenhower Range

The outcrop is located at the east-facing cliff of the Eisenhower Range about 10 km north of Mount Nansen. Although the geological map suggests that the basement is granite (GANOVEX-TEAM 1987), it consists of folded greyish-black to greenish-grey, low-grade metapelite with intercalated fine-grained white quartzite. The contact with the overlying sedimentary succession may be sharp or vaguely indicated by a diffuse transition. The basal unit is characterized by diffuse sub-horizontal stratification of poorly sorted, sand- to boulder-sized clasts in muddy matrix, and locally shows soft sediment deformation (Fig. 4c, 4d). The second unit is a largely unstratified clast-bearing mudstone with lateral transition into poorly sorted, matrix-supported conglomerate. The coarse-grained components in both layers are dominantly angular, and identical to the rocks in the underlying metamorphic basement, but additionally include cm-sized quartz clasts. These two basal units are up to 2 m thick and can be described as a diamictite of uncertain origin. Clear evidence for a glacigenic origin, e.g., in the form of striated clasts, striated base, or greater component diversity, is lacking. Similar deposits were not observed with certainty at other exposures along the cliff of the Eisenhower Range during a helicopter survey. The overlying clastic succession is made up of alternating beds of coarse- to fine-grained, mostly well-sorted conglomerate and minor pebbly sandstone. The two coarsest sedimentary units, with clasts up to 15 cm diameter, occur at the base and about 16 m higher in the section (Fig. 2, 4c). Thin grey, green or light-brown siltstone/sandstone layers are interbedded occasionally and may be traced laterally over at least several tens of metres. The conglomerates form an approximately 35 m high cliff. The overlying 10-15 m consist of a slope-forming, bedded sedimentary unit. Considering the weathering style and the photos taken from the helicopter, it is probably composed of fine-grained conglomerate and sandstone with intercalated decimetre- to metre-thick dark-grey to black fine-grained rocks. Clast types at this section are similar to those at Thern Promontory and Anderton Glacier, but large light-brown siltstone/sandstone intraclasts are locally more abundant.

Skinner Ridge

An outcrop east of Mount Mackintosh (Skinner Ridge) at about 2000 m was briefly visited during a reconnaissance survey. A 25-35 m thick sedimentary section is exposed between two thick Ferrar sills; the lower sill is at least 200 m thick and most likely equivalent to the cliff-forming sill at the south and east side of the Eisenhower Range. The sedimentary section is dominated by medium-grained, lithoclast-rich grey sandstone with yellowish-brown weathering colours; fine- and coarse-grained, pebbly sandstones are subordinate. Pebbles are frequently concentrated at and near the base of sandstone units, representing gravel lag deposits. The most abundant clasts are well-rounded and angular quartz pebbles up to 30 cm size, quarzite/quarzitic sandstone clasts, laminated greenish-grey and black, sandy pelitic intraclasts up to 60 cm size. In addition, abundant fossil tree trunks occur (BOMFLEUR et al. 2011 this vol.). Dark-grey to black, carbonaceous lacustrine pelite is locally preserved underneath the erosive base of intraclast-rich sandstone units (Fig. 4e, 4f). Detrital carbonaceous material is frequently concentrated on bedding planes within fine- to medium-grained sandstone. We did not find any igneous unit that could be interpreted as a basalt flow as suggested by CASNEDI & DIGIULIO (1999), but a <1 m thick mafic dike that cross-cuts the sandstone beds.

Timber Peak

Three sedimentary units separated by sills are exposed around Timber Peak. The lowermost unit rests on top of the Priestley Schists at about 2400 m elevation east of a narrow distributary glacier between Timber Peak and Mount New Zealand. These basal unit is difficult to access and was only observed from helicopter. It is 50-70 m thick and consists of greyish, bedded clastics, most likely sandstone and minor conglomerate, subdivided into four benches. The second sedimentary section occurs on top of a c. 80 m thick mafic sill, and is accessible at the southern ridge of Timber Peak. This succession is 30-40 m thick and composed of trough cross-bedded, medium- to coarse-grained, light-grey to light-brown sandstone, locally rich in greenish siltstone intraclasts of up to 30 cm diameter. Another thick sill separates these sandstones from the uppermost, about 80 m thick outcrop already described by RICKER (1964) and GAIR et al. (1965), which is located at the south-western slope of Timber Peak above 2840 m. This outcrop is mainly made up of medium-grained, trough cross-bedded sandstone with minor proportions of coarse-grained and pebbly sandstone. Sandstone composition changes from lithoclast-rich in the lower part to quartz-rich in the upper part of the section. Silicified tree trunks occur at several horizons, but are particularly abundant at the base of the examined section. A succession of carbonaceous, ripple cross-laminated fine-grained sandstone, dark-grey siltstone, black claystone, and coal is interbedded between 9 m and 25 m of the section. Some of these fine-grained strata are very rich in fossils (BOMFLEUR et al. 2011 this vol.). Approximately 15 m of the middle part of the section were covered by talus and snow during our investigations, but the relatively flat slope suggests that another fine-grained unit is present. The summit of Timber Peak is formed by a mafic sill.

Priestley Glacier

The outcrop is an impressive 800 m high cliff at the north side of the upper Priestley Glacier 7 km west of Shafer Peak (Fig. 5a). The only accessible points for helicopter landings are the top of the cliff at about 3350 m elevation and a narrow sandstone plateau in the upper third of the cliff. The thickness of the units was calculated by extrapolating the 10-m-section measured briefly during the landing, and by using photos and elevations taken from the helicopter. Above the Priestley Schists, a succession of siliciclastic and volcaniclastic deposits of about 250 m total thickness is exposed (excluding mafic, mainly intrusive igneous rocks with a total thickness of about 300 m). The base of the clastic succession is made up of approximately 70 m of coarse-grained deposits, probably sandstone and minor conglomerate of the Section Peak Formation. They are overlain by an alternation of slope-forming, finer-grained units and sandstone sheets ranging in thickness from about 6 m to 25 m. At the section measured close to the landing site, an about 8 m thick unit consisting of grey, occasionally clayey siltstone, fine-grained sandstone and coal is exposed between two cliffs formed by medium- to coarse-grained sandstone containing gravel lag deposits. A fining-upward trend and several carbonaceous interbeds were observed. A 1.2 m thick coal seam occurs at the top, and is cut by the erosive base of the overlying sandstone. In total, five such fine-grained intercalations are exposed in the steep cliff walls, with metre-thick coal seams evident at least in two cases. The overlying units are mafic volcaniclastic deposits related to local explosive volcanic events (Exposure Hill-type events), silicic tuffaceous sand/siltstones of the Shafer Peak Formation, pillow lavas forming the top of the cliff, and intrusive igneous bodies.

Shafer Peak

Shafer Peak provides excellent exposures at its east-facing cliff, which is steep and difficult to access (Fig. 5b). However, the base of the Section Peak Formation is accessible at about 3000 m elevation at the south ridge running from Shafer Peak towards the Priestley Glacier. The sedimentary succession rests upon greyish, weathered granitic rocks with large K-feldspar phenocrysts. The colour of the basement rocks changes from grey to red in an interval of about 5-10 m below the unconformity. The basal 2-4 m of clastic rocks are poorly organized, moderately- to well-sorted, quartz-rich conglomerate with clast sizes of up to 5 cm. A large snowfield covers more than 10 m of the following section, but greyish, lithoclast-rich sandstone blocks occur in the scree. Above the snowfield a more than 25 m thick series of medium- to coarse-grained, mainly trough cross-bedded quartzose sandstone is exposed. There is at least one internal erosion surface marked by a sharp grain-size increase and red-brown diagenetic Fe-oxide staining. The sedimentary succession is overlain by a mafic sill. The central part of the section at Shafer Peak was not investigated, but the uppermost 60 m of the Section Peak Formation and the overlying volcaniclastic deposits and Kirkpatrick lava flows are accessible along the gently sloping north ridge connecting Shafer Peak and Mount Hewson, above c. 3100 m elevation. This section consists of four medium- to coarse-grained, trough cross-bedded sandstone units of 4-8 m thickness, each overlain by poorly exposed fine-grained sandstone, siltstone and mudstone of similar thickness (Fig. 5c). An about 10 m thick sill occurs at the base of the third sandstone unit. The fine-grained units locally contain intensely rooted horizons as well as plant-bearing beds. The sandstone units contain intraclasts of siltstone and coal as well as thin pebbly sandstone layers. The uppermost 13 m of the Section Peak Formation are dominantly fine-grained, but contain thin erosive sandstone layers and several tuffaceous beds of fine-grained sand- to silt-size, which are rich in silicic shards. The Section Peak Formation is overlain by a c. 20 m thick succession of coarse-grained mafic volcaniclastics and a fossiliferous black shale that is in turn overlain by 53 m of reworked silicic tuffs. The latter part of the section was proposed as the type section for the Shafer Peak Formation (SCHÖNER et al. 2007). A microflora from the black shales below the Shafer Peak Formation indicates an Early Jurassic age (MUSUMECI et al. 2006).

Point 3350

South of Mount Adamson in the Deep Freeze Range, a moderately steep ridge protrudes from a prominent east- to southeast-facing slope, extending from almost the top of the peak marked by Point 3350 on the topographic map (1:250,000) down towards east-southeast. The ridge exposes an approximately 700 m thick section from the basement to the Kirkpatrick lava flows. It was measured briefly during a one-day visit; the given thicknesses of individual units are estimates mainly based on GPS elevations. The base of the Section Peak Formation is exposed at this ridge at about 2615 m above sea level. A thin gravel layer with sub-rounded clasts up to 15 cm, composed mainly of quartz, mica-schist and quartzite, covers weathered granitic basement. The overlying 14 m are dominated by medium- and coarse-grained sandstone locally interbedded with up to 30 cm thick pebbly sandstone and fine- to medium-grained conglomerate layers. This greyish, lithic-rich sandstone is overlain by about 45 m of white to yellowish, generally well-sorted, coarse-grained quartzose sandstone that is separated into two units by an approximately 65 m thick mafic sill (Fig. 5d). Fine-grained layers contain abundant biotite; coarse-grained layers are characterized by mainly large-scale, locally small-scale trough cross-bedding. Some sandstone beds contain thin gravel layers, light-grey, mica-rich, fine-grained sand- to siltstone intraclasts, permineralized tree stems and coal fragments. The contact with the overlying, about 90 m thick sill-like intrusive body, is sharp and shows evidence for thermal alteration of the uppermost cm of the sandstone. The sill contains a number of sandstone rafts, which range in size from a few metres to almost 20 m thickness and at least 50 m lateral extension. Large rafts are located in the upper part of the sill. Sedimentary textures in these sandstones are in places plastically deformed, and the sill is vesicular near the contact with the sandstone rafts. The overlying section consists of thick volcaniclastic deposits and sills, eventually overlain by pillow lavas, further volcaniclastic deposits, and lava flows.

Mount Adamson

The adjacent southeast-facing slope south of Mount Adamson provides excellent exposures of the sedimentary succession and the overlying lavas between c. 2700 m and 3300 m elevation. Accessibility is limited by the steepness of the slope. The southern part of this slope, which represents a concordant stratigraphic succession, was studied on a one-day trip from the base of the pillow lavas at about 3240 m down to a small plateau on the basement at about 2680 m. Parts of the succession were covered by snow on that day. Thicknesses are based on elevations taken by GPS and on photos taken during a helicopter survey. The base of the section above the granite is covered by talus and snow, but the small plateau at about 2700 m probably represents the top of the basement. An at least 180 m thick sill occurs at or close to the boundary between the basement and the sedimentary succession. On top of the sill, medium- to coarse-grained sandstone of about 170-180 m thickness is exposed. In the lower part, the sandstone is intruded by two sills of 10 m and 20 m thickness, respectively. In the upper 150 m, four separate 20-55 m thick units are suggested by slope morphology. Grain sizes range from fine-grained sand to fine-grained gravel without prominent grain-size trend; siltstone is only evident from intraclasts, which locally reach up to 0.5 m size. In the southern part of the outcrop, the siliciclastic succession is overlain by about 60 m of coarse-grained volcaniclastic deposits (Exposure Hill-type deposits) and a 45-50 m thick series of reworked silicic tuffs (Shafer Peak Formation). The cliff above is formed by two about 50 m thick mafic lava units, but the contacts of the units are not exposed. The lowermost 10-15 m of the lavas show pillow textures.

Archambault Ridge and N' Plateau

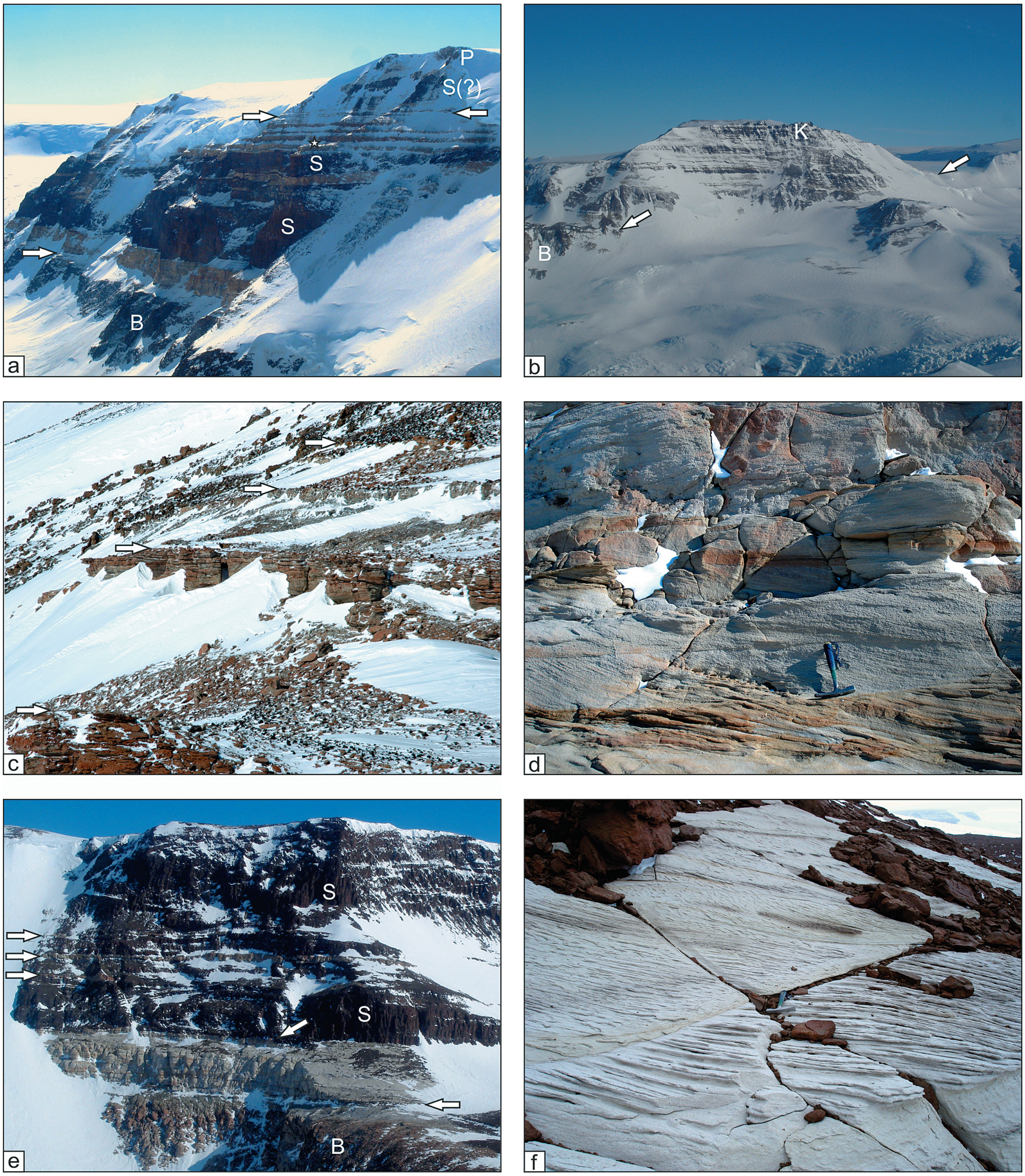
Two good outcrops of the Section Peak Formation are exposed at Archambault Ridge: The first (Archambault N' Plateau, Fig. 5e) is located at the base of the cliff arising from a small plateau (~2800 m) north of the western end of Archambault Ridge; the second is located at Archambault Ridge itself, about 5 km east of the Polar Plateau escarpment. Although CASNEDI & DI GIULIO (1999) described an outcrop at Archambault Rigde without specifying the detailed location, our observations differ from their descriptions at both sections. At Archambault N' Plateau an about 65 m thick sedimentary succession rests unconformably on deeply weathered basement (Granite Harbour intrusives). The uppermost 4-5 m of the granite are greyish in colour, whereas the typical rock colour underneath this weathering zone is red. The unconformity is flat on a km-scale, but has a local relief on dm- to m-scale. The sedimentary succession starts with a 1-1.5 m thick poorly organized, coarse-grained, pebbly sandstone, containing grey siltstone intraclasts. Permineralized tree trunks up to 0.5 m long are a major component of the following ~1 m thick poorly sorted conglomerate (BOMFLEUR et al. 2011 this vol.). The conglomerate is strongly cemented by iron oxides resulting in a brownish stain on weathered surfaces. Most other siliciclastic deposits have pale grey to light-brown colours. The following, more than 60 m thick section consists of light-grey to light-brown, cross-bedded, medium- to coarse-grained and pebbly sandstone (Fig. 5f). Pebbles are concentrated on individual cross-bedding planes or at the base of cross-bedded units. Sandstone units of 2-15 m thickness are separated by erosion surfaces, which are occasionally overlain by poorly bedded and sorted layers rich in light-grey to grey-green siltstone intraclasts. Thin fine-grained sandstone and siltstone with plane lamination or ripple cross-lamination are interbedded locally, but their lateral extension is limited to a few metres. The uppermost 4 m exposed below the cliff-forming sill are slightly coarser-grained than the typical sandstones dominating the outcrop. Three further sandstone sheets with a total thickness of 20-25 m are intercalated between the cliff-forming sills.

At Archambault Ridge, about 70 m of sandstones are exposed between the granitic basement and a mafic sill. The siliciclastic rocks are largely similar to those of Archambault N' Plateau with respect to grain-size, components and sedimentary struc-

Fig. 5: The Section Peak Formation in the Deep Freeze Range. (a) Approximately 800 m high cliff at the north side of Priestley Glacier, view from the helicopter towards northwest. The base of the Section Peak Formation above metamorphic basement rocks (B) is marked by a snow-covered slope (lower arrow). The Section Peak Formation consists predominantly of sandstone in the lower and middle part, and by alternating sandstone sheets and interbedded fine-grained units in the upper part. The c. 8 m thick fine-grained unit directly above the small plateau (asterisk) has been measured, and contains a 1.2 m thick coal seam at the top. The siliciclastic deposits of the Section Peak Formation are overlain by mafic (dark-brownish, upper arrows) and silicic (light-brownish) volcaniclastic deposits. The sedimentary section has been intruded by thick mafic sills (S) and is overlain by pillow lavas (P). (b) East cliff of Shafer Peak (3600 m), view from the helicopter towards northwest. The base of the Section Peak Formation above the basement (B, Granite Harbour intrusives) is exposed at the south ridge of Shafer Peak (left arrow); the upper part of the Section Peak Formation can be measured along the north ridge (right arrow). The summit of Shafer Peak is made up of Kirkpatrick lava flows (K). Height of the cliff from top basement (B) to the summit is approximately 600 m. (c) Upper part of the Section Peak Formation at the north ridge of Shafer Peak, showing alternating units of cross-bedded fluvial sandstone and poorly exposed fine-grained units (grey, partly carbonaceous siltstone, fine-grained sandstone, claystone). The top of each sandstone unit is marked by an arrow. The middle sandstone unit is about 4.5 m thick. (d) Trough cross-bedded, fluvial sandstones indicating relatively homogenous northern paleocurrent directions at the ridge close to Point 3350. Length of hammer 28.5 cm. (e) About 65 m of sandstone overlying granitic basement (B) at Archambault N' Plateau. The uppermost 4-5 m of the granite, underneath the base of the clastic succession (right arrow), are weathered and show a greyish rock colour. The sedimentary rocks are capped by Ferrar sills with large columnar joints (S). The base of the lowermost sill is not strictly stratiform (inclined arrow). Three thin layers or rafts of sediment can be observed within the cliff-forming sills forming the cliff wall (left arrows). (f) Cross-bedded fluvial sandstone in the middle part of the section at Archambault N' Plateau, suggesting northeastern paleocurrent orientation. The large-scale cross-bedding sets are made up of coarse- and medium-grained sandstone layers with slightly curved foresets. Gravel layers are intercalated occasionally. The lateral extension of individual cross-bedding sets ranges from metres to a few tens of metres. Length of hammer 28.5 cm.

Abb. 5: Die Section Peak Formation in der Deep Freeze Range. (a) Etwa 800 m hohe Steilwand an der Nordseite des Priestley Glacier, Blick vom Helikopter Richtung Nordwest. Die Basis der Section Peak Formation über metamorphem Grundgebirge (B) wird durch einen Schnee bedeckten Absatz gekennzeichnet (Pfeil unten). Im unteren und mittleren Teil besteht die Section Peak Formation überwiegend aus Sandstein, im oberen Teil aus einer Wechselfolge von Sandstein und Feinklastika. Die ~8 m mächtige feinkörnige Einheit unmittelbar oberhalb des kleinen Plateaus (Stern) wird am Top von einem 1.2 m mächtigen Kohleflöz abgeschlossen. Die Siliziklastika der Section Peak Formation werden von mafischen (dunkelbraun, Pfeile oben) und felsischen (hellbraun) Vukaniklastika überlagert. In die Sedimentabfolge sind mächtige Lagergänge eingedrungen (S), am Top sind Kissenlaven ausgebildet (P). (b) Ostwand des Shafer Peak (3600 m), Blick vom Hubschrauber Richtung Nordwest. Die Basis der Section Peak Formation über dem Grundgebirge (B, Granite Harbour Intrusives) ist am Südgrat aufgeschlossen (Pfeil links); der höhere Teil der Section Peak Formation kann entlang des Nordgrats aufgenommen werden (Pfeil rechts). Der Gipfel des Shafer Peak wird aus Kirkpatrick-Laven aufgebaut (K). Höhe der Wand vom Top des Grundgebirges (B) bis zum Gipfel etwa 600 m. (c) Höherer Teil der Section Peak Formation am Nordgrat des Shafer Peak mit abwechselnd schräg geschichtetem fluviatilen Sandstein und schlecht aufgeschlossenen Feinklastika. Der Top jeder Sandsteineinheit ist durch einen Pfeil gekennzeichnet. Die mittlere Sandsteineinheit ist etwa 4.5 m mächtig. (d) Trogförmig schräg geschichtete, fluviatile Sandsteine belegen relativ homogene nord-wärtige Paläoströmungsrichtungen am Grat nahe Punkt 3350. Länge des Hammers 28.5 cm. (e) Etwa 65 m Sandstein auf granitischem Grundgebirge (B) am Archambault N' Plateau. Die obersten 4-5 m des Granits unmittelbar unter der klastischen Abfolge (Pfeil rechts) sind verwittert (graue Gesteinsfarbe). Die Sedimente werden von einem oder mehreren Lagergängen mit großen säuligen Klüften überlagert (S). Die Basis des Lagergangs ist nicht horizontbeständig (schräger Pfeil). Innerhalb des/der Wand bildenden Lagergänge sind drei geringmächtige Sedimentpakete zu sehen (Pfeile links). (f) Schräg geschichteter fluviatiler Sandstein im mittleren Abschnitt des Profils am Archambault N' Plateau mit nordöstlicher Orientierung der Paläoströmung. Die großmaßstäblichen Schrägschichtungssets werden aus grobkörnigen und mittelkörnigen Sandlagen gebildet. Einzelne Sets haben eine laterale Ausdehnung im Bereich einiger Meter bis weniger Zehnermeter. Länge des Hammers 28.5 cm.

tures. However, individual units cannot be correlated directly, and there are some differences in detail. The section at Archambault Ridge contains thin dark-grey carbonaceous layers at about 20 m above the base of the sedimentary succession. We could not verify the presence of "basic igneous interbeds" suggested by CASNEDI & DI GIULIO (1999) at approximately the same stratigraphic position. Some sandstone units contain pebbles and cobbles up to 15 cm in diameter at the base of cross-bedding units. The gravel components are dominated by well-rounded clasts of quartz, granite, and quartzite, but also include a variety of moderately- to subrounded clasts (quartz, dark metamorphic rocks, schist, phyllite, rarely sandstone and light-grey siltstone intraclasts). The overlying mafic igneous rock does not show textures typical for Kirkpartick lava flows as proposed by CASNEDI & DI GIULIO (1999), but is a homogenous, non-vesicular sill with chilled margin and mm-thick fused sediment rim.



Exposure Hill

On the plateau west of Exposure Hill, at least 25 m of medium- to coarse-grained sandstone are enclosed by mafic sills. The sandstone is dominantly large-scale trough cross-bedded, and locally contains greenish siltstone intraclasts and coaly plant fragments. Sandstone units of similar thickness are also exposed in the Vantage Hills and Illusion Hills, but were only observed by helicopter. These units commonly have irregular base and top, and partly occur as large rafts enclosed within the sills.

Section Peak

Section Peak at 2417 m is located in the northern part of Lichen Hills in the upper Rennick Glacier area. A prominent, about 90 m thick Ferrar sill separates the sedimentary section into two major units, which were proposed as the type section for the Section Peak Formation (COLLINSON et al. 1986). The lower part was re-measured at the south-facing cliff of a spur between Section Peak and the Rennick Glacier, where the contact between granite and overlying siliciclastics is exposed. The upper part of the section was measured at a small sediment pinnacle preserved on the large plateau that is formed by the top of the sill (Fig. 6a). Sandy conglomerate and medium- to coarse-grained sandstone overlie weathered granite and fill a local relief of 1-2 m. The conglomerate contains quartz (<5 cm), feldspar (<0.5 cm), light-brown siltstone (<20 cm), sandstone (<5 cm), dark metamorphic grains (<5 cm), and coal clasts (<40 cm). Scours with up to 1 m relief filled by sandstone containing pebble clasts and coalified wood fragments are abundant. On average, cross-bedding sets become thicker and better organized towards the top, but grain-size variations at every few decimetres are common. The uppermost 8 m beneath the sill are characterized by erosion surfaces that incise up to 4 m deep and contain lag deposits rich in coalified wood or peat fragments. Grain sizes vary from silt to medium-size gravel. Fining-upward units of 2-4 m grade from cross-bedded sandstone to ripple cross-laminated sandstone; thin siltstone layers are locally present. Bedding planes especially of medium- to fine-grained sandstone contain abundant coalified plant debris. The upper unit on top of the sill begins with about 5 m of large-scale trough cross-bedded sandstone that is overlain by 4 m thick black and sandy, lacustrine siltstones. The intrusion level of the sill is not constant throughout the outcrop and apparently cross-cuts this pelite unit. Poorly sorted intraclast-rich conglomerate with sharp erosive base, trough cross-bedded medium- to coarse-grained sandstone, and thin interbeds of fine-grained sandstone or siltstone containing abundant mica and plant detritus make up the upper 13 m of the section (Fig. 6b). The orientation of cross-bedding sets suggests transport toward the north.

Barren Bluff

About 13 m of sandstone is exposed below an approximately 120 m thick, cliff-forming sill in the Sequence Hills. The lower part of the section is covered by talus and snow; however, it presumably rests on metamorphic basement rocks as in cliff-faces along the Sequence Hills. The sedimentary succession consists of fine-grained sandstone to fine-grained conglomerate. Grain sizes are not homogeneous, and differ from bed to bed. Two sandy conglomerate layers contain angular to sub-rounded quartz clasts and many coal fragments of highly irregular shape, some of which may represent plant axes or peat fragments. The sandstone directly beneath the mafic sill shows columnar joints of 1.2 m length.

Myosotis Nunatak

Myosotis Nunatak is located in the upper Rennick Glacier area east of Sequence Hills. About 14 m of sandstone between two sills are exposed at the east side of the elongate Nunatak. Both upper and lower contacts of the sills show mm-thin fused margins and an up to 1 dm thick zone with stronger cementation of the sandstone. The sedimentary rocks are composed of 1-5 m thick units of grey to light-brown, fine- to coarse-grained, cross-bedded sandstone and locally contain fine-grained gravel layers.

Johannessen Nunatak

Another small outcrop of about 15 m of sandstone enclosed by sills is located at Johannessen Nunatak north of Sequence Hills. The section is characterized by homogeneous medium- to coarse-grained sandstone. Bedding textures are also homogeneous and mainly show large-scale geometries. The thickest bedding set is a 2 m thick sub-horizontally laminated sandstone, which can be traced laterally across the entire outcrop (10-15 m).

Roberts Butte

Roberts Butte forms part of the Outback Nunataks and is the northernmost outcrop studied. The siliciclastic rocks were deposited on weathered granitic basement rocks containing large feldspars and granite pegmatite veins. The approximately 25 m thick section is dominated by alternating beds of cross-bedded, medium- and coarse-grained pebbly sandstone. Some

Fig. 6: The Section Peak Formation in the upper Rennick Glacier area and in the Southern Cross Mountains. (a) Upper part of the section at the type locality at Section Peak, above the c. 90 m thick sill; view towards southeast over the Rennick Glacier with the Mesa Range in the background. The top of the sill (S) is not stratiform; it partly gives way to irregular intrusive bodies (I) with columnar joints pointing into various directions. About 4 m of carbonaceous lacustrine siltstone (top indicated by inclined arrows) is overlain by 13 m of fluvial channel deposits, which are again capped by a Ferrar sill (upper arrow). (b) Detail of the outcrop indicated on (a). Lacustrine black siltstone (LS) overlain by an erosion surface, poorly sorted intraclast-rich conglomerate (IC) and large-scale trough cross-bedded channel sandstone (CS). Folding rule 1 m. (c) Lichen Hills, view towards southeast (Lemasters Bluff). The base of the Section Peak Formation (left arrow) is a flat surface on kilometre-scale. On top of the basement (B, Granite Harbour Intrusives) two thin layers of sedimentary rocks (right arrows) are separated by Ferrar sills with vertical columnar joints. Height of granite cliff (B) slightly more than 200 m. (d) Upper part of the section at Chisholm Hills West Ridge. The plateau is made up of fine-grained tuffaceous sandstone and siltstone (lower arrow). The overlying, predominantly greyish pelites are poorly exposed and had to be excavated (grey streak next to the red sample bag). They are overlain by a fluvial channel-form sandstone (upper arrow). (e) Ripple cross-laminated sandstone from the section at Chisholm Hills West Ridge, slightly below the plateau shown in (d). The darker laminae consist of quartzo-felspathic sandstone, the bright (whitish) laminae are rich in ash-sized silicic shards, suggesting that distal felsic explosive volcanism took place contemporaneously with the deposition of the uppermost Section Peak Formation. Length of hammer 28.5 cm.

Abb. 6: Die Section Peak Formation im Bereich des oberen Rennick Glacier und in den Southern Cross Mountains. (a) Höherer Teil des Aufschlusses an der Typlokalität Section Peak, oberhalb des etwa 90 m mächtigen Lagergangs; Blick Richtung Südost über den Rennick Glacier. Die Obergrenze des Lagergangs (S) ist nicht horizontbeständig, sondern geht in unregelmäßige Intusivkörper (I) über. Etwa 4 m kohliger, lakustriner Siltstein (Top durch schräge Pfeile gekennzeichnet) werden von 13 m fluviatilen Rinnenablagerungen überlagert, darüber ein weiterer Lagergang (Pfeil oben). (b) Detail des Aufschlusses auf Bild (a). Lakustriner, schwarzer Siltstein (LS) wird erosiv von schlecht sortiertem, Intraklast reichem Konglomerat (IC) und großmaßstäblich trogförmig schräg geschichtetem Sandstein (CS) überlagert. Meterstab 1 m. (c) Lichen Hills, Blick Richtung Südost (Lemasters Bluff). Die Basis der Section Peak Formation (Pfeil links) ist im Kilometermaßstab eine ebene Fläche. Auf dem Grundgebirge (B, Granite Harbour intrusives) sind zwei Sandsteinlagen (Pfeile rechts) und Lagergänge mit vertikaler, säuliger Klüftung zu sehen. Höhe der Granitwand (B) etwas mehr als 200 m. (d) Oberer Abschnitt des Profils am Chisholm Hills Westgrat. Auf dem Plateau stehen feinkörniger tuffitischer Sand- und Siltstein an (Pfeil unten). Die überlagernden, überwiegend grauen Pelite sind schlecht aufgeschlossen. Sie werden erosiv von fluviatilem Rinnensandstein überlagert (Pfeil oben). (e) Rippel geschichtete Sandsteine des Profils Chisholm Hills Westgrat, etwas unterhalb des Plateaus auf Bild (d). Die dunkleren Laminae bestehen aus Quarz- und Feldspat reichem Sand, die helleren Laminae enthalten zahlreiche vulkanische Glasscherben, die von aktivem felsischen Vulkanismus während der Ablagerung des obersten Abschnitts der Section Peak Formation zeugen. Länge des Hammers 28.5 cm.

layers contain abundant greenish-grey siltstone intraclasts. Silicified or coaly plant axes are present in several units.

Vulcan Hills

An approximately 180 m thick succession of the Section Peak Formation rests on crystalline basement in the Vulcan Hills. The outcrop was not measured, but visited during a brief re-sampling survey of the Upper Triassic *Dicroidium*-bearing carbonaceous shale horizon described by TESSENSOHN & MÄDLER (1987). The fossil site occurs on a flat ridge in the upper part of the section (BOMFLEUR et al. 2011 this vol.). Light-grey, medium-grained, lithoclast-rich sandstone is most abundant throughout the Vulcan Hills section. Whitish quartz-rich sandstone was observed locally, mainly near the base of the sedimentary succession.

Chisholm Hills W-Ridge

From the summit of Chisholm Hills (3080 m) a ridge extends northwest to a nameless summit, and then west into the glacier-filled depression between Chisholm Hills and Mount Carson. A thick Ferrar sill forms a steep cliff at the lower end of the ridge above the glacier. A sedimentary section of about 70 m thickness is accessible directly above this sill. At the southern part of the exposure the sediments were intruded by a wedge-shaped, non-stratiform sill, which is connected to the thick sill at the base of the outcrop. A continuous, almost horizontal sequence was measured in the northern to central part of the exposure. The sedimentary section starts with a 7-8 m thick fining-upward unit of predominantly trough cross-bedded and locally plane-bedded sandstone, followed by 4-5 m of light-brown to grey claystone. This claystone is massive and lacks discrete bedding planes, although horizontal bedding is vaguely suggested by colour differences. It is overlain by about 30 m of generally medium-grained and well-sorted sandstone, separated into several sub-units by flat to gently inclined erosion surfaces. A less than 2 m thick, massive to laminated light-brown clayey siltstone layer is interbedded, but pinches out by erosion of the overlying sandstone over a distance of about 50 m. There is a minor fining-upward trend towards the upper part of the section, where ripple-laminated sandstone, locally containing silicic shard laminae, becomes more abundant (Fig. 6e). The sandstone is overlain by a bench-forming carbonaceous, fine-sandy, laminated siltstone of up to 2 m thickness, which again is cut by erosion by a medium-grained sandstone. The following part of the section has been measured about 100 m further south starting on a plateau (Fig. 6d). As a result, uncertainty remains about the stratigraphic continuity. Ripple cross-laminated medium- to fine-grained quartzose and tuffaceous sandstones form a prominent plateau. Poorly exposed, scree-covered grey, green and black pelites dominate the above 15-18 m. Several horizons contain small angular, partly scoriaceous clasts with red weathering colours, probably representing pyroclastic fragments. The latter are concentrated in a 1.5 m thick black, poorly sorted unit that may represent a tuff layer. The top of the Section Peak Formation is made up of about 5 m thick, medium- to coarse-grained sandstone beds with abundant coaly plant axes and tree trunks. Although the contact with the overlying tuffaceous sandstone/siltstone unit is obscured by a sill intrusion, the Section Peak Formation is probably directly overlain by the Shafer Peak Formation at this outcrop.

Other small outcrops of the Section Peak Formation occur scattered in the southeastern part of the Chisholm Hills and in the small depression directly north of Mount Carson, which was used as camp site during GANOVEX IX. They comprise mainly well-sorted medium- to coarse-grained, quartzose and arkosic sandstones. Garnet-rich heavy mineral placers are abundant. Compressed plant axes and impressions of tree trunks up to 20 cm diameter and layers with abundant yellowish siltstone intraclasts occur locally. The thickness is difficult to estimate due to the flat slope, but may be 10-15 m.

Stewart Heights

At Stewart Heights, about 30 km east of the southern Mesa Range, a 16 m thick package of conglomerate and sandstone is exposed between granitic basement rocks and a mafic sill forming the summit of one of the peaks. The granite is deeply weathered; at least the upper 20 m show grey to greenish-grey weathering colours. The uppermost 6 m of granite are strongly decomposed; the rock fabric is almost grit-like. Several pegmatite veins of 1-20 cm thickness with coarse muscovite, feldspar and quartz are present in the granite. The overlying sedimentary section begins with about 1 m thick poorly sorted, medium- to coarse-grained, mainly grain-supported conglomerate with weak sub-horizontal stratification. Pebbles are partly imbricated. The clasts are rounded to well-rounded quartz (<15 cm), granite and granite pegmatite (<10 cm), black rounded amphibolite (<8 cm), black sub-angular metapelite, and grey siltstone (<3 cm). The matrix is medium- to coarse-grained sand and locally mud with abundant white mica. The overlying 15 m consist of alternating layers of cross-bedded sandstone and conglomerate with grain-sizes varying from medium-grained sand to medium-sized gravel. These deposits are rich in quartz, but also contain dark clasts (probably metapelite or amphibolite).

Runaway Hills West

The northwest spur of the Runaway Hills is a northwest-southeast-trending ridge formed by mafic Ferrar intrusives. On the steep south side of this ridge, decametre-thick rafts of sandstone, black sedimentary rocks and coal within Ferrar intrusives are tilted almost vertically, suggesting that the ridge probably represents a major dyke system. On the north side of the ridge, about 20 m of flat-lying quartzose sandstone, thin coaly sandstone, and siltstone are enclosed between Ferrar sills. The sandstone is dominantly coarse-grained and homogeneously trough cross-bedded. Grain sizes range from medium-grained sand to fine gravel.

DISCUSSION AND CONCLUSIONS

The Section Peak Formation is a continental, predominantly siliciclastic unit that was deposited on top of pre-Devonian basement of the Wilson Terrane over much of southern north Victoria Land. The basal unconformity has a local relief on a metre-scale, but is apparently flat on kilometre-scale (Fig. 6c).

The thin diamictite observed above weathered basement in the Eisenhower Range may represent locally re-deposited weathering products, transported by solifluction (flow structures) or debris-flow processes. However, the latter are difficult to explain considering the flat basement surface that suggests a low-relief landscape. An alternative explanation would be a glacial origin of the diamictite, although no evidence of glacial transport was observed.

The total thickness of the Section Peak Formation is about 200 m in the Eisenhower and Deep Freeze ranges. Further north, only incomplete sections are preserved. The occurrence of *Dicroidium* assemblages more than 100 m above the basal unconformity indicates Triassic age for the lower and middle part of the Section Peak Formation in the area between Vulcan Hills and Timber Peak (TESSENSOHN & MÄDLER 1987, BOMFLEUR et al. 2011 this vol.). On the other hand, detrital zircons of Early Jurassic age were found only 20 m above the basement at Section Peak (GOODGE & FANNING 2010), and COLLINSON et al. (1986) observed a devitrified volcanic glass fragment in a sample from the 25 m thick section at Roberts Butte. This glass fragment is probably related to contemporaneous explosive volcanism, which is only known from the Early Jurassic. These observations suggest that in the area of the upper Rennick Gacier and the Outback Nunataks, the Section Peak Formation is either strongly condensed, or the onset of sedimentation was later than further south, eventually not until the Early Jurassic.

Thick conglomerates are only evident in the Eisenhower Range (Fig. 3). Observations from the helicopter along the east-facing cliff of the Eisenhower Range suggest that these conglomerates do not thin out towards north, but more likely become finer-grained and grade into sandstones. However, this needs to be verified by measuring several sections along the Eisenhower Range cliff between Mount Nansen and Mount New Zealand. The conglomerates are dominated by clasts most likely from the Wilson Terrane basement. The dominance of clast-supported, moderately- to well-sorted, cross-bedded conglomerate, interbedded with cross-bedded sandstone and rare fine-grained low-energy deposits, and the abundance of erosion surfaces, suggest deposition by a gravel-bed braided fluvial system.

Medium- to coarse-grained, trough cross-bedded sandstone is the dominant lithology of the Section Peak Formation (Fig. 3). Thick sandstone successions with only minor interbedded conglomerate, intraclast-conglomerate or pelite are abundant in all parts of the working area except in the southern Eisenhower Range, where sedimentary rocks above the basal conglomerate units have been removed by erosion. These sandstones are typical sandy braided-stream deposits, as suggested by COLLINSON et al. (1986). An aeolian origin of some sandstones at Archambault Ridge, as suggested by CASNEDI & DI GIULIO (1999), could not be confirmed by our observations. Archambault Ridge and the better exposed outcrop at Archambault N' Plateau are composed entirely of channel-bed fluvial deposits; evidence of flood-plain deposits is only preserved as pelite intraclasts. Apart from sedimentary textures, the abundance of coarse-grained sand, pebble concentrations at the base of cross-bedding sets, the occurrence of intraclasts, the moderate roundness of grains, and the presence of mica argues against aeolian origin throughout the sections. Supposed bidirectional cross-bedding at Timber Peak has been used to discuss a possible tidal environment (CASNEDI & DI GIULIO 1999). However, we did not find evidence for bidirectional cross-bedding; all observed sedimentary textures are typical for braided-river sandstones.

In the upper part of the Section Peak Formation, lithologies become more variable, and sandstone units alternate with carbonaceous siltstone-mudstone-claystone units of several metres thickness, including up to 1 m thick coal beds (Fig. 3). These sedimentary rocks were most likely deposited in flood-plain, back-swamp, and locally in lacustrine environments. Interbedded thin silicic shard-rich layers of fine-grained sand- or silt-size in the uppermost Section Peak Formation indicate that explosive silicic volcanism took place contemporaneously with siliciclastic deposition. The homogeneous, fine grain-size of the silicic pyroclastic material suggests that the volcanism was distal, and most likely not within the sedimentary basin itself. These tuffs or tuffites are lithologically similar to deposits described from the uppermost Lashly Formation in south Victoria Land (ELLIOT et al. 2006) and the Hanson Formation in the central Transantarctic Mountains (ELLIOT 1996). The youngest part of the Section Peak Formation was deposited during the Early Jurassic as suggested by palynological and radiometric data (NORRIS 1965, PERTUSATI et al. 2006, GOODGE & FANNING 2010). The Section Peak Formation is capped either by mafic volcaniclastic deposits related to local eruptions generated during early Ferrar sill intrusions into wet sediments (VIERECK-GOETTE et al. 2007), or by the approximately 50 m thick Shafer Peak Formation that consists of reworked silicic tuff.

The Ferrar units at the type locality of the Section Peak Formation were described as lavas by GAIR et al. (1965), and later reinterpreted as sills (COLLINSON et al. 1986), which coincides with our observations. We did not find any evidence for the effusion of mafic lava flows contemporaneously with the deposition of the Section Peak Formation, as hypothesized by DI GIULIO et al. (1997) and CASNEDI & DI GIULIO (1999). All observed contacts between igneous Ferrar rocks and siliciclastic deposits of the Section Peak Formation indicate intrusive origin. Where exposed, base and top of the mostly non-vesicular igneous units have cm-thick chilled margins and adjacent sedimentary rocks typically have mm-thick fused margins. As expected in porous sandstones, the thermal effect of contact metamorphism is comparatively low. Nevertheless, sedimentary rocks below very thick sills may show columnar joints of up to 1 m length. Clear evidence for the intrusive nature of the igneous units is given by the fact that most of these units are not strictly stratiform over long distances, but locally cut through different sedimentary layers.

Petrographic studies by COLLINSON et al. (1986) indicate that the sandstones of the Section Peak Formation have a crystalline basement source and an acid to intermediate magmatic arc source. In contrast, DI GIULIO et al. (1997) argued that the volcanic grains derive from the "basalt flows", which can conclusively be regarded as sills, as pointed out above. Furthermore, our preliminary petrographic data show that volcanic grains are only partly mafic in composition, but frequently derive from felsic volcanic source rocks, and thus confirm the observations of COLLINSON et al. (1986). The Section Peak Formation consists of sandstones with a wide compositional range from quartz-rich to arkosic to lithoclast-rich; the former two are indicated by whitish, light-grey or light-brown rock colours, the latter by medium-grey rock colours and commonly more rounded weathering surfaces at the outcrop. The variable sandstone composition suggests that there were probably more than two compositionally distinct source areas. It is likely that the volcanic grains are derived from a magmatic arc that was probably active along the Panthalassan margin of Gondwana during the Triassic and Early Jurassic (Collinson et al. 1994). This is further supported by the abundance of Early Jurassic zircon grains in a sample from Section Peak (Goodge & Fanning 2010).

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