Geological Field Trips and Maps

A comprehensive 1:250,000 scale geological map of the Convoy Range and Franklin Island quadrangles (Victoria Land, Antarctica)

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A comprehensive 1:250,000 scale geological map of the Convoy Range and Franklin Island quadrangles (Victoria Land, Antarctica)

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Cover page Figure
Above: Mt Smith looking from SE to NW. Ferrar Dolerite overlies Granite Harbour Intrusives along Kukri Erosion Surface. Ferrar Dolerite occurs also at the bottom of the Granite Harbour Intrusives.
Below: SE to NW aerial view of Mt Murray.

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ABSTRACT

A comprehensive geological map of the Convoy Range - Franklin Island USGS quadrangles (Victoria Land, Antarctica) integrates previous geological maps with new field data collected during the 2017/18 and 2018/19 austral summers by the XXXIII and XXXIV ItaliAntartide expeditions. This new geological map allows a complete coverage of Victoria Land, by filling the gap between the GIGAMAP program (a German / Italian agreement of cooperation to produce new geological maps of Victoria Land), to the north, and the maps by the New Zealand Antarctic program, to the south.
The Lower Paleozoic basement is overlain by flat-lying Devonian to lower Jurassic cover of sedimentary and igneous rocks. The mapping highlighted some key features of this region, such as the scarce occurrence of rocks of the Wilson Metamorphic Complex, the occurrence of mafic rocks belonging to the Granite Harbour Intrusive Complex and the possible activity of faulting with hundreds of meter of vertical offset, linked to the post-Ross Orogeny tectonics. This new map can be used as the starting point for any future geological investigation in this region.

Keywords: geological mapping, dolerite, sandstone, granite, Convoy Range, Victoria Land, Antarctica.

INTRODUCTION

The region mapped in this work (Fig. 1 A, B) was first visited during the heroic age of Antarctic exploration. J.C. Ross was the first to discover the Transantarctic Mountains, the Ross Sea, and the Ross Ice Shelf, and he also reached the volcanic Franklin Island (Ross, 1847). In 1899, Borchgrevink's second expedition landed on Possession Islands, Coulman Island, Franklin Island and Ross Island, and in 1901 collection of geological samples in this region was made by the team of Scott's first expedition. During Shackleton's Nimrod Expedition (1907-09), T.W.E. David and D. Mawson were the first geologists to visit the region of Mawson and Priestley glaciers. David's party man-hauled their sledges from Cape Royds, crossed the ice tongues of Mawson and David Glaciers, the Nansen Ice sheet, ascended through Backstair Passage to the Polar Plateau, and finally reached the South Magnetic Pole. During their journey they visited rock outcrops at Prior Island, Cape Irizar, Backstair Passage and Mt Crummer (David, 1909).
Substantial geological work in northern Victoria Land (NVL) was done by the Northern Party of Scott's second expedition (1910-13), who surveyed the area around Terra Nova Bay in 1912, before being forced to winter-over in a snow-cave on Inexpressible Island (Priestley, 1914, 1915; Smith and Priestley, 1921).
In the 1960s several New Zealand field parties (Ricker, 1964; Skinner and Ricker, 1968a, b) surveyed Victoria Land and this quadrangle, establishing the overall framework of regional geology (Nathan and Skinner, 1972). Mapping contributions were provided by Gunn and Warren (1962) and Gair et al. (1969).
During the 1981-82 International NVL Project, New Zealand and US geologists (Stump, 1986) investigated the field relations, petrology and geochemistry of the Paleozoic granitoids (Borg et al., 1986, 1987) and the Jurassic tholeiites (Elliot and Foland, 1986; Elliot et al., 1986).
During the 1982-83 season, NVL was visited by the German expedition GANOVEX III (Roland, 1984), which produced a 1:500,000 geological map of NVL (GANOVEX Team, 1987), excluding the Convoy Range - Franklin Island quadrangles.
Since the 1985-86 season, Italian geologists have investigated the region between the David and the Mariner glaciers, and a 1:500,000 geological map of the same area (Carmignani et al., 1987) was produced; this map neither did cover the Convoy Range - Franklin Island quadrangles. The German and Italian expeditions of the following years triggered the publication of several papers, but only a few are related to these quadrangles (Kleinschmidt and Matzer, 1992; Tessensohn et al., 1992; Molzahn et al., 1996; Rossetti and Storti, 1998; Storti et al., 2008; Rocchi et al., 2009).
Another mapping contribution is due to Pocknall et al. (1994), whose map, however, does not cover the northernmost part of the Convoy Range quadrangle.
In 1995 German and Italian geologists signed an agreement of cooperation (the GIGAMAP program) to produce new geological maps of NVL at the scale of 1:250,000 (Capponi et al., 2002; Pertusati et al., 2016). The GIGAMAP program does not include the Convoy Range and the Franklin Island quadrangles, the Mt Joyce and Relief Inlet being the southernmost quadrangles of the program.
Cox et al. (2012) supplied a major contribution with a geological map covering the entire southern Victoria Land, but not the northernmost part of the Convoy Range and Franklin Island quadrangles.
The aim of this mapping project has been to fill a gap, providing a new comprehensive geological map that integrates our new field map data with the map by Cox et al. (2012), to obtain a new 1:250,000 map covering the Convoy Range and the Franklin Island USGS quadrangles.

METHODS

The topographic base for this geological map resulted from a mosaic of two 1:250,000 USGS quadrangles, concerning the Convoy Range and Franklin Island (Fig. 1A). The Franklin Island quadrangle covers a huge marine area, with two small islands in the eastern part, i.e., the Beaufort and Franklin islands, which we were not able to visit and map. Therefore, we preferred to exclude the part covering the sea and the

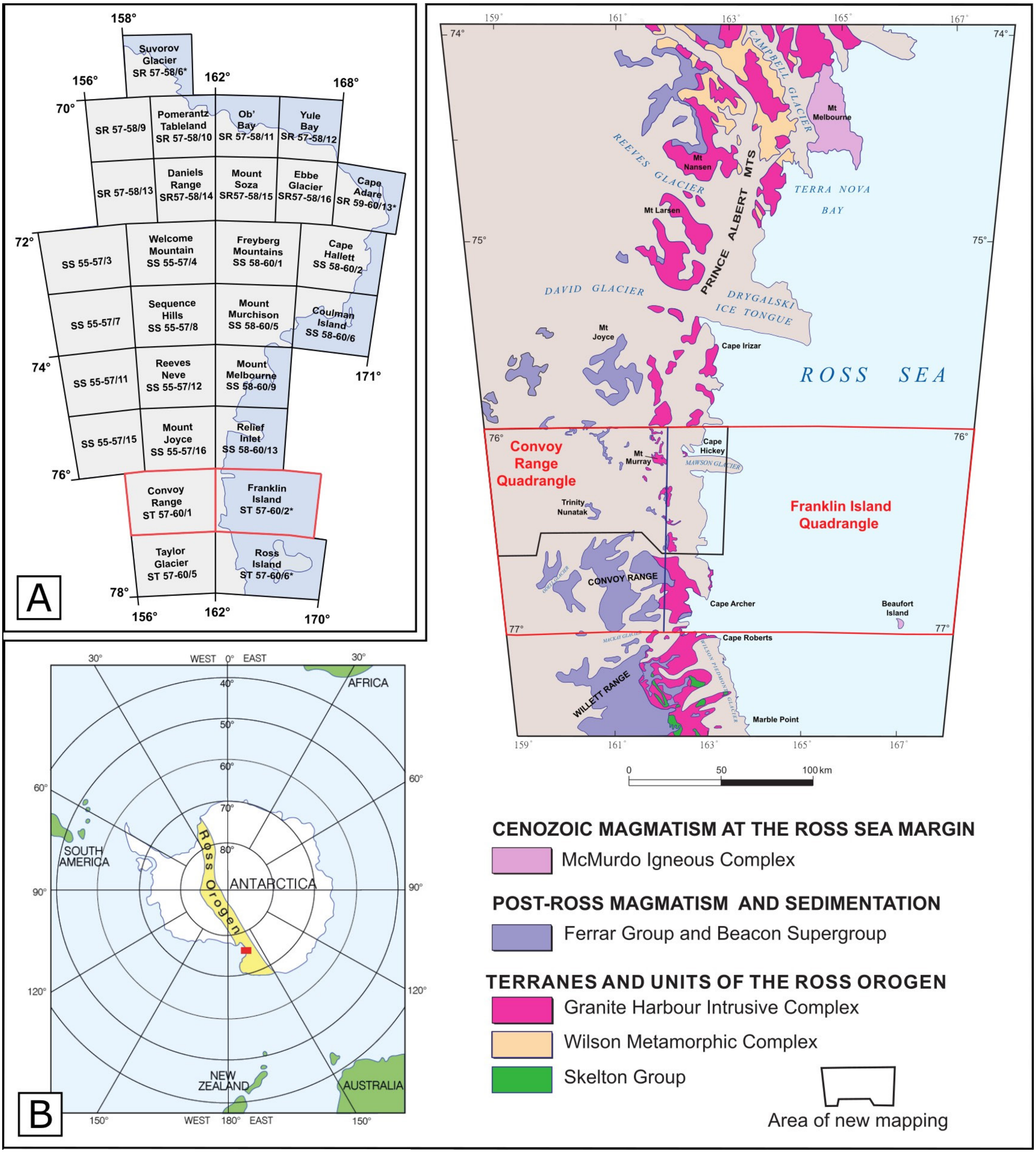

Fig. 1 - A) Index to adjoining sheets. The Convoy Range and Franklin Island quadrangles are squared in red; B) location diagram and tectonic sketch map of Victoria Land.

unvisited islands and join the trimmed area with the Convoy Range quadrangle. New mapping was performed during 2017/18 and 2018/19 austral summers in the context of the XXXIII and XXXIV ItaliAntartide expeditions.
Field activity was helicopter-supported and was organised in daily missions from the Italian Mario Zucchelli Station (2017/2018) and from a base camp at Starr Nunatak (75°54′S, 162°35′E), to better reach the most distant sectors of the study area (2018/2019). Mapping was coupled with the collection of rock samples that we later studied at the

microscale, to better characterize the different lithologies. New data are joined with the already published geological map by Cox et al. (2012), covering the southern part of the quadrangles. The QGIS 2.18 software was used to produce the topographic base and a digital database. The final map layout was made with Adobe Illustrator CC 2018.

GEOLOGICAL SETTING

Victoria Land (Fig. 1B) includes parts of the Transantarctic Mountains, one of the most extended mountain ranges on Earth, and extends inland to the Polar Plateau. The basement of the Transantarctic Mountains is genetically linked to the late Neoproterozoic - early Paleozoic Ross Orogeny, whereas the present mountain chain represents the western shoulder of the West Antarctic Rift System that initiated at ~85 Ma (Fitzgerald, 2002), when crustal extension between East and West Antarctica resulted in the break-up of this part of Gondwana (Lawver and Gahagan, 1994).

The Convoy Range - Franklin Island quadrangles (Fig. 1A, 1B) encompass lower Paleozoic granitic basement and a flat-lying cover of sedimentary and igneous rocks, spanning in age from Devonian to Early Jurassic.

The lower Paleozoic basement consists of large bodies of the Cambrian - Lower Ordovician Granite Harbour Intrusive Complex (Fig. 2), enclosing minor bodies of metamorphic rocks of the Wilson Terrane (WT).

The WT includes low- to high-grade metamorphic rocks of Neoproterozoic - Cambrian age, deformed and metamorphosed in the late Neoproterozoic - early Paleozoic Ross Orogeny.

The Granite Harbour Intrusive Complex is predominantly made up of syn- to post-tectonic granitoids emplaced in older rocks. Radiometric age data (U–Pb on zircon) indicate that the emplacement sequence of the Granite Harbour Intrusive Complex dates back to around 580 - 590 Ma (Goodge, 2020), with a main phase of activity roughly between 520 and 480 Ma (Bomparola et al., 2007; Giacomini et al., 2007).

A major, though largely unrecorded, tectonic event resulted in the uplift of the Ross Orogen rocks, by as much as 30 km, followed by deep erosion to form an almost flat landscape by Devonian time (c. 411 Ma). The resulting Kukri Erosion Surface (Gunn and Warren, 1962; Woolfe and Barrett, 1995) can be traced along the whole length of the Transantarctic Mountains (Isbell, 1999). On this peneplain, the deposition of the Beacon Supergroup occurred (Fig. 2), which is an up to 2.5 km thick epicontinental sandstone-dominated succession of Devonian to Early Jurassic age (Woolfe and Barrett, 1995). The Beacon rocks are slightly deformed and generally the bedding dips gently to the west. In places they are crosscut by minor brittle faults and disrupted by younger intrusions.

During the early stages of Gondwana breakup (Early Jurassic), the Ferrar Large Igneous Province was emplaced (Fig. 2). In Victoria Land, the Ferrar LIP is mainly represented by the voluminous sills of the Ferrar Dolerite (Ferrar, 1907; Gunn, 1962, 1963; Gunn and Warren, 1962; Marsh, 2004; Boudreau and Simon, 2007; Airoldi et al., 2011, 2012; Muirhead et al., 2012). The Ferrar Dolerite covers and locally incorporates the Beacon sandstones, disrupting their stratigraphy.

The coeval extrusive equivalents of the Ferrar Dolerite sills are the Kirkpatrick Basalt and associated mafic pyroclastic deposits of the Mawson Formation (Gunn and Warren, 1962; Grindley, 1963; Elliot et al., 1999; Elliot, 2000; Ballance and Watters, 2002; Elliot et al., 2006; Ross et al., 2008); both are scarcely represented in this area.

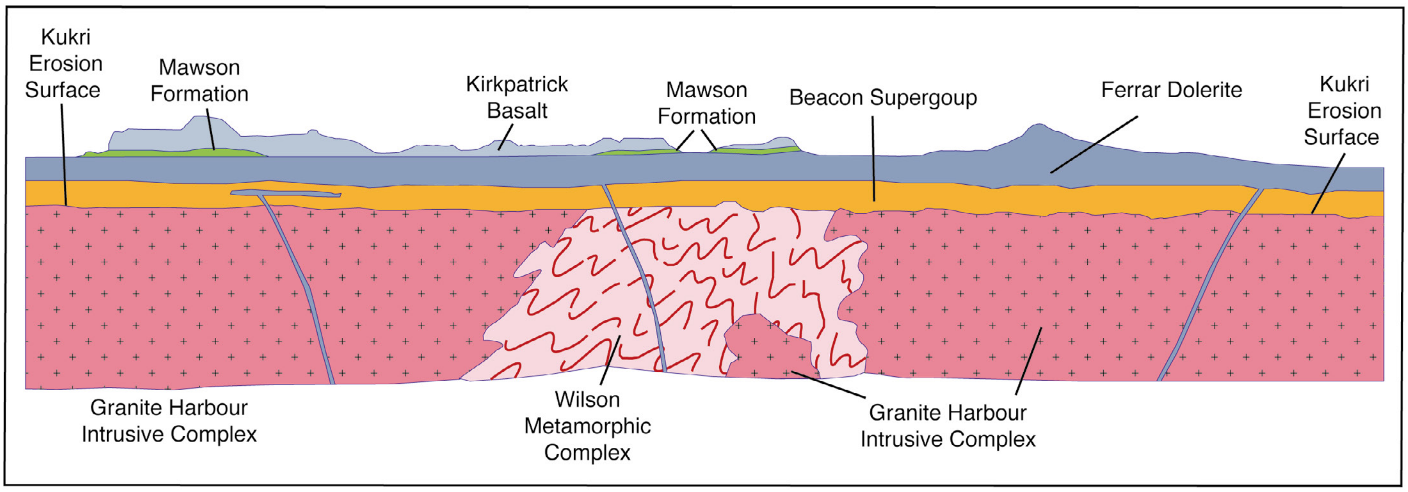

Fig. 2 - Cartoon showing the simplified tectonic evolution of Victoria Land. Not to scale.

LITHOSTRATIGRAPHY

Wilson Terrane

Wilson Metamorphic Complex (Wg)

In the mapped area the Wilson Metamorphic Complex (Wg) includes low-to medium-grade micaschist, paragneiss and metaconglomerate (Fig. 3A). The occurrence of such rocks is very limited in the area and restricted to small bodies and slivers at Mt Murray, south of Mt Chetwynd and at Walker Rocks. The protoliths of these metasediments appear to belong to a unique succession of fine- to medium-grained siliciclastic sediments, with possible intercalations of conglomerate, of Neoproterozoic - Cambrian age. They underwent metamorphic re-equilibration at different metamorphic grades during the Ross Orogeny (Carmignani et al., 1987; Lombardo et al., 1987; Casnedi and Pertusati, 1989; Skinner, 1989; Castelli et al., 1997). Evidence of contact metamorphism, due to the emplacement of the Granite Harbour granitoids locally occur, e.g. in the Walker Rocks area (Molzahn et al., 1996; Capponi et al., 2020).

Sub-volcanic Unit (Wf)

The Johnnie Walker Formation (Wf) represents a low-grade metamorphic sub-volcanic unit (Molzahn et al., 1996) that crops out in the southern area of Walker Rocks, in the centre of the study area, where it unconformably overlies the metamorphic rocks of the Wilson Terrane (Tessensohn et al., 1992; Molzahn et al., 1996). The Johnnie Walker Formation is made of andesite, brecciated andesite, rhyolite and granophyre that appear undeformed and contact metamorphosed by the subsequent emplacement of the Granite Harbour Intrusives. The age of these rocks is unknown, but they must have been formed before the early Paleozoic emplacement of the Granite Harbour Intrusive Complex. A whole rock and mineral isochron supplied a Rb/Sr age of 525 ± 5 Ma (Molzahn et al., 1996) for an undeformed granite at Walker Rocks (Tab. I).

Granite Harbour Intrusive Complex

The Granite Harbour Intrusive Complex crops out along a N-S headland, close to the coast of the Ross Sea, and is

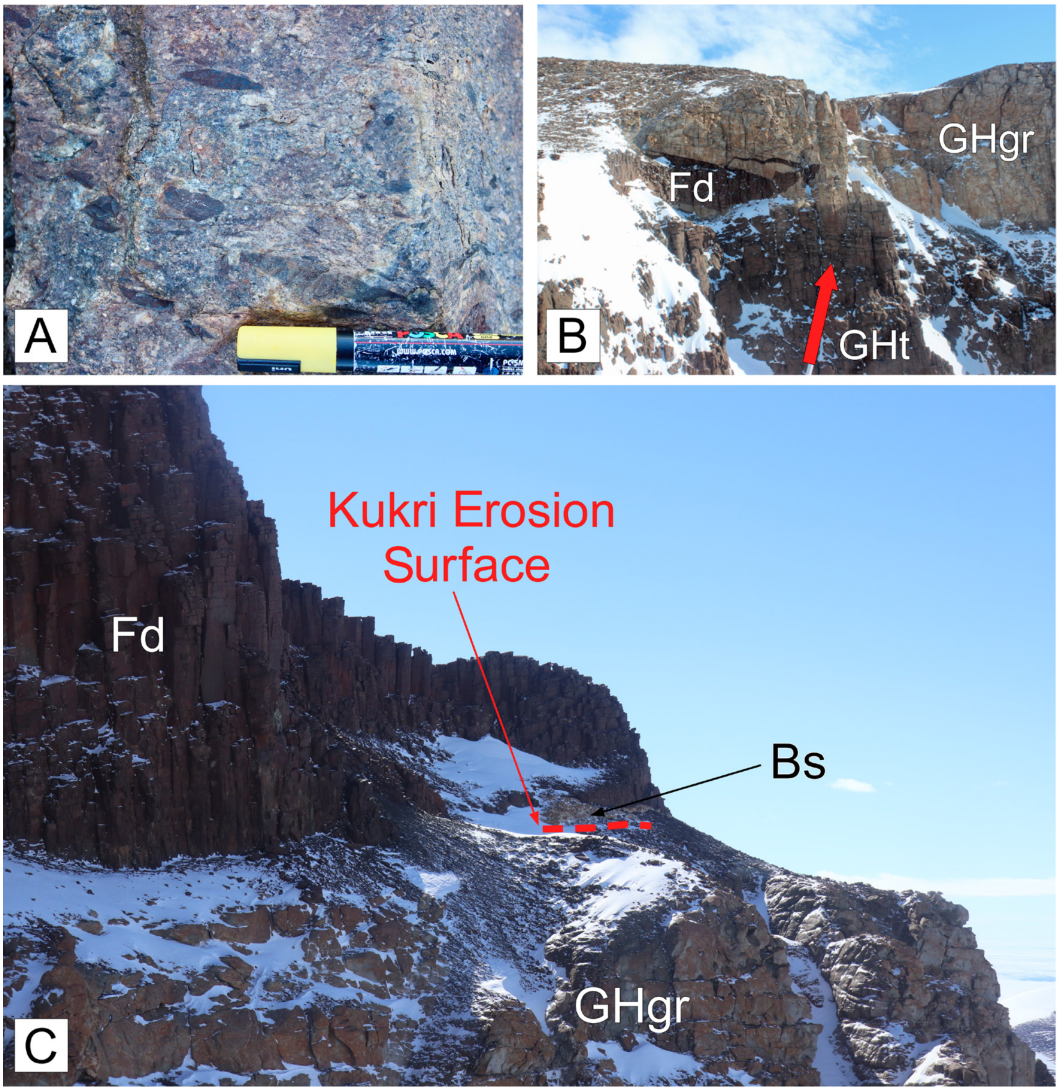

Fig. 3 - A) Deformed metaconglomerate cropping out at the Walker Rocks, showing flattened clasts; B) gradational contact (red arrow) between the Granite Harbour Granite (GHgr) and the Granite Harbour microgabbro-microdiorite (GHt) in the Mt Smith area. A Ferrar Dolerite dyke (Fd) crosscutting the granite is present; C) Beacon sandstone body (Bs) above the Kukri Erosion Surface, between the granitic basement (GHgr) and the overlying dolerite (Fd) in the Mt Smith area.

Table 1 - Synoptic table of the radiometric age determinations cited in the text.

UNIT / FORMATION	METHOD	AGE MA	REFERENCE
Ferrar Volcanic Suite / Kirkpatrick Basalt	K/Ar whole-rock	178	Elliot and Foland, 1986
Ferrar Volcanic Suite / Kirkpatrick Basalt	$^{40}Ar/^{39}Ar$ whole rock	174.2 ± 1	McIntosh et al., 1986
Ferrar Volcanic Suite / Ferrar Dolerite	K/Ar whole-rock isochron	174 ± 10	Brotzu et al., 1988
Ferrar Volcanic Suite / Ferrar Dolerite	$^{40}Ar/^{39}Ar$ on feldspar and biotite	176.7 ± 8	Fleming et al. 1997
Ferrar Volcanic Suite	U/Pb on zircon	182	Elliot et al., 2021

Granite Harbour Intrusive Complex Larsen Granodiorite	Rb/Sr on biotite	498 ± 11	Borsi et al., 1987
Granite Harbour Intrusive Complex Irizar Granite	Rb/Sr mineral - whole rock isochron	525 ± 5	Molzahn et al., 1996
Granite Harbour Intrusive Complex Irizar Granite	$^{40}Ar/^{39}Ar$ on biotite and amphibole Rb/Sr whole rock isochron	486.1 ± 8.4	Di Vincenzo et al., 2003
Granite Harbour Intrusive Complex Gabbro - diorite rocks	U/Pb on zircon	513 - 526	Rocchi et al., 2004
Granite Harbour Intrusive Complex Irizar Granite	U/Pb on zircon	489 ± 4.4	Rocchi et al., 2009
Granite Harbour Intrusive Complex Vegetation lamprophyres	$^{40}Ar/^{39}Ar$ on amphibole	490	Rocchi et al., 2009

characterised by weakly foliated to unfoliated, syn-to post-kinematic granite, granodiorite and syenogranite, (local name Larsen Granodiorite; after Gunn and Warren, 1962), associated with post-tectonic granite (local name Irizar Granite; after Gunn and Warren, 1962); diorite and gabbro occur as well. Such rocks represent a mostly calc-alkaline orogenic suite interpreted as the magmatic signature of an active continental margin, linked to the subduction event of the Ross Orogeny.

In the Dry Valleys, owing to detailed mapping, the Granite Harbour Intrusive Complex was subdivided into several petrological suites (Smillie, 1992; Allibone et al., 1993a, b; Allibone and Wysoczanski, 2002; Read et al., 2002). Though such subdivision is not reported in the map, Cox et al. (2012) recognised that in the Benson and Mackay glaciers area the magmatic rocks mainly belong to the DV1a (hornblende-biotite granitoids) and DV2 (alkali-calcic monzonite, quartz monzonite and granitic plutons) suites, whereas in the northern part of the map the Granite Harbour rocks are mainly undifferentiated.

The dominant rock type in the Convoy Range-Franklin Island area is a metaluminous biotite granite and granodiorite (GHgr) that ranges from fine-grained mostly equigranular granodiorite to coarse-grained inequigranular to strongly porphyritic monzogranite and syenogranite. Radiometric data from adjoining areas indicate that the emplacement sequence of the Granite Harbour Intrusive Complex spanned nearly 30 Ma, from 521 to 481 Ma (Bomparola et al., 2007; Giacomini et al., 2007). In the adjoining Relief Inlet quadrangle, Borsi et al. (1987) obtained a biotite Rb/Sr cooling age of 498 ± 11 Ma (Tab. I). It is therefore reasonable to assume a late Cambrian - Early Ordovician age of emplacement for the granitoid rocks of these quadrangles. At many places, the dominant granitoid type is intruded by a younger homogeneous, unfoliated, equigranular, medium- to coarse-grained syenomonzogranite, characterised by pink-red colour due to the presence of pink alkali feldspar (local name Irizar Granite). Major Irizar Granite outcrops are in the northern cliffs of Mt Gauss and in western slopes of Mt Endeavour. A whole rock and mineral isochron supplied a Rb/Sr age of 525 ± 5 Ma (Molzahn et al., 1996) for undeformed Irizar Granite at Walker Rocks.

In adjoining quadrangles, a U/Pb zircon age of emplacement of 489 ± 4.4 Ma (Rocchi et al., 2009), was obtained at Cape Irizar (Relief Inlet Quadrangle), in agreement with Di Vincenzo et al. (2003), who supplied an age of 486.1 ± 8.4 Ma by $^{40}Ar/^{39}Ar$ and Rb/Sr techniques on biotites (Tab.I). Irizar Granite also occurs as m-thick dykes with the same emplacement age (Rocchi et al., 2009).

A suite of gabbro-diorite rocks (GHt) occurs in the western cliffs of Mt Smith and belongs to the Granite Harbour Intrusive Complex (Capponi et al., 2020). These rocks are unfoliated to weakly foliated and crop out beneath the light-grey granite. Their field appearance resembles the Ferrar Dolerite, but clear gradational contacts (Fig. 3B) with respect to the overlying granites demonstrates their genetic relation with the Granite Harbour Intrusives. Rocchi et al. (2004), based on U/Pb method on zircon, report an age range of 513-526 Ma (Tab. I) for the GHt in the Northern Foothills (Mt Melbourne Quadrangle).

Other occurrences of Granite Harbour Intrusive Complex rocks are the Vegetation lamprophyres, a widespread association of hypabyssal tabular intrusions (Rocchi et al., 2009) with hundreds of sub-vertical, about 1-m thick mafic dykes with an overall strike between NE-SW and NNE-SSW. Dykes sampled at Bruce Point, Cape Hickey and Mt Endeavour supplied a $^{40}Ar/^{39}Ar$ age on amphibole around 490 Ma (see Rocchi et al., 2009, for details).

Beacon Supergroup

The Beacon Supergroup is represented by sandstone-dominated strata and its lithostratigraphy takes advantage from the fossiliferous content; its base is marked by a remarkable peneplain surface, which is equivalent to the Kukri Peneplain as defined in the Dry Valleys (Barrett et al., 1986). This surface formed as a consequence of a prolonged period of uplift, deep erosion, local dissection, weathering and planation. In the northern part of the map, this erosion surface is visible at Mt Smith (Fig. 3C; Fig. 4), Mt Gauss, Mt Murray, Mt Chetwynd and at the eastern slopes of Mt Endeavour.

The Beacon Supergroup is subdivided into the Devonian Taylor Group and the Permian to Lower Jurassic Victoria Group (Harrington, 1965). The two groups are separated with little or no angular unconformity by the Maya Erosion Surface (Harrington, 1965; Pocknall et al., 1994) that represents a time gap of about 86 to 109 Ma (Cox et al., 2012).

The Taylor Group rocks (Bt) comprise mainly quartzose sandstone (Hamilton and Hayes, 1963; Webb, 1963; McElroy, 1969; McKelvey et al., 1970). Cox et al. (2012) provided full details of the lithostratigraphic features. Rocks of the Taylor Group mainly crop out in the Staten Island Heights area, but extensive outcrops are also present at Mt Razorback and Battleship Promontory, where the contact with the overlying Victoria Group is also visible.

Victoria Group rocks (Bv) represent a classic Gondwanan sequence, with basal glacial beds overlain by mainly fluvio-lacustrine deposits, including prominent coal measures and abundant plant fossils both in the Permian (the characteristic *Glossopteris* flora) and in the Middle to Upper Triassic (the *Dicroidium* flora) (Veevers, 1988) and other plant fragments, leaves, rootlets, petrified logs and tree stumps. Full details of the lithostratigraphic features are provided by Cox et al. (2012). Major outcrops of Victoria Group rocks are located at Coombs Hills and Allan Hills (southwestern part of the map), where they comprise

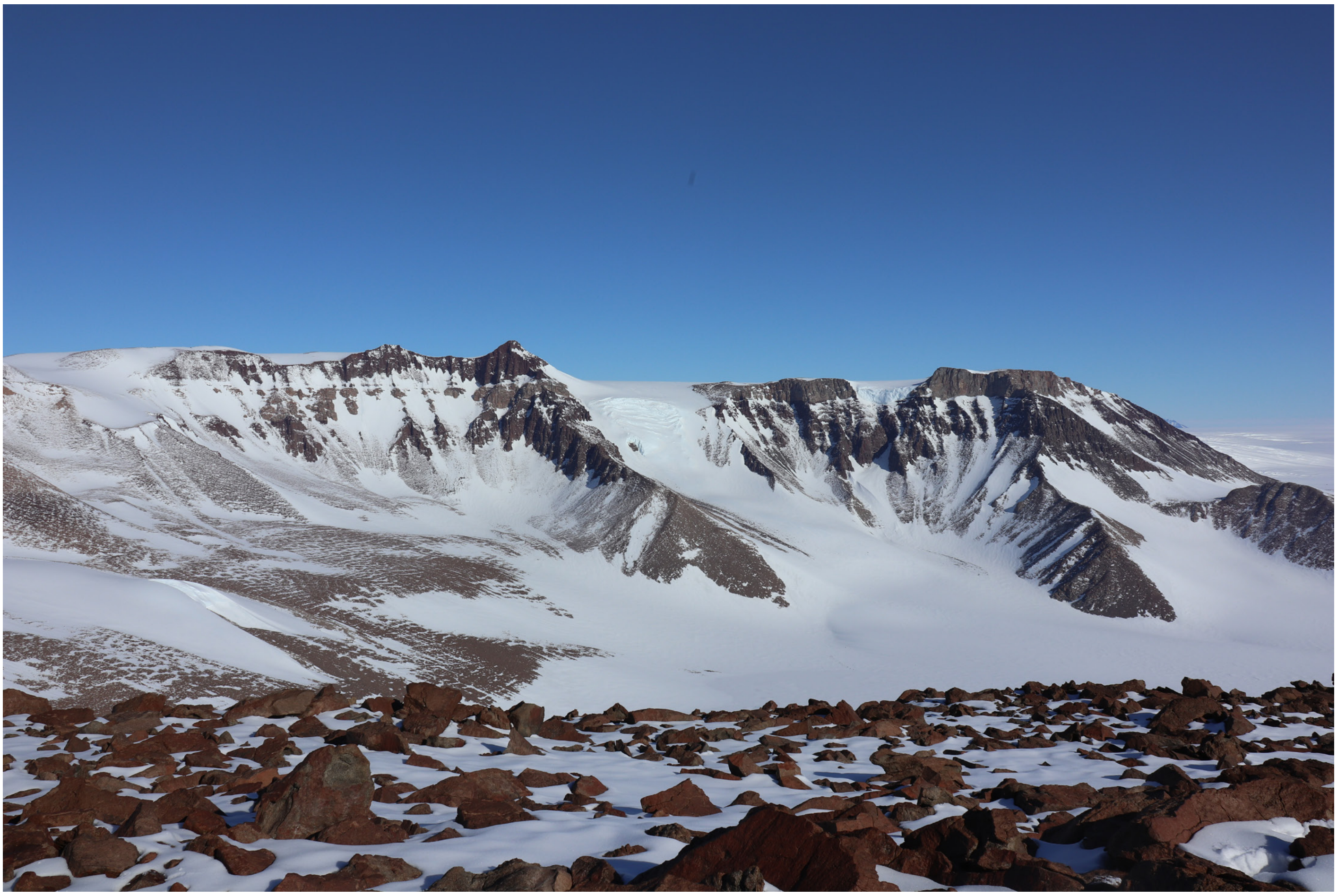

Fig. 4 - View from SE of the Mt Smith area. Ferrar Dolerite is emplaced above the Granite Harbour Granite and the Granite Harbour microgabbro-microdiorite.

granular and pebbly quartzofeldspathic sandstone, with lesser quartz pebble conglomerate, siltstone and mudstone. In the northern part of the mapped area, the outcrops of Beacon sandstones are quite limited, and only at Mt Smith small bodies of sandstone rest above the erosion surface (Fig. 3C), sandwiched between the granitic basement and the overlying dolerite (Capponi et al., 2020). In a cliff south of Mt Chetwynd, a level of Beacon sandstone, which is continuous for about 1 km, overlies the Granite Harbour granitoid, but the erosion surface itself is not visible; the upper part of the cliff consists of Ferrar Dolerite. Elsewhere the Beacon outcrops are restricted to 100- to 1000-m large sedimentary rafts, floating in and truncated by the Ferrar Dolerite (Fig. 5A, 5B, 5C; Fig. 6).

In the northern part of the mapped area, beds rich in organic matter occurs at McLea Nunatak (Fig. 5D, 5E),

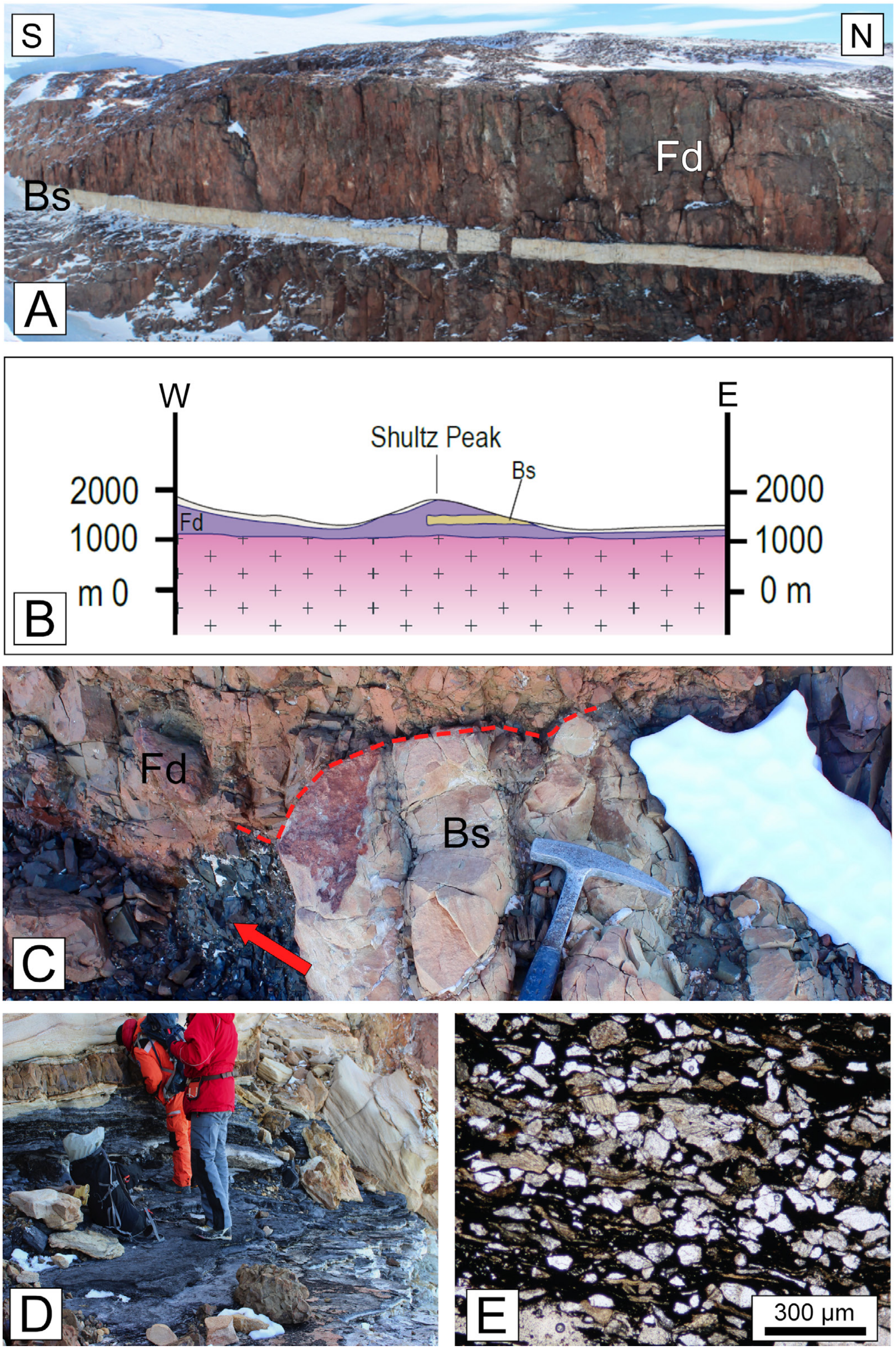

Fig. 5 - A) Undifferentiated Beacon sandstone body (Bs), floating in the Ferrar Dolerite (Fd) in the Shultz Peak area. Note that Beacon strata are truncated by the emplacement of the mafic rocks; B) cross section across the Shultz Peak, showing the relations between the Beacon raft (Bs), the Ferrar Dolerite (Fd) and the underlying Granite Harbour Granite; C) beds of Beacon sandstone (Bs), truncated by Ferrar Dolerite (Fd), at the Reckling Peak. Red arrow indicates organic matter; D) beds of Beacon sandstone rich in organic matter at McLea Nunatak; E) microscopic aspect of organic rich levels of Beacon sandstone (parallel Nicols).

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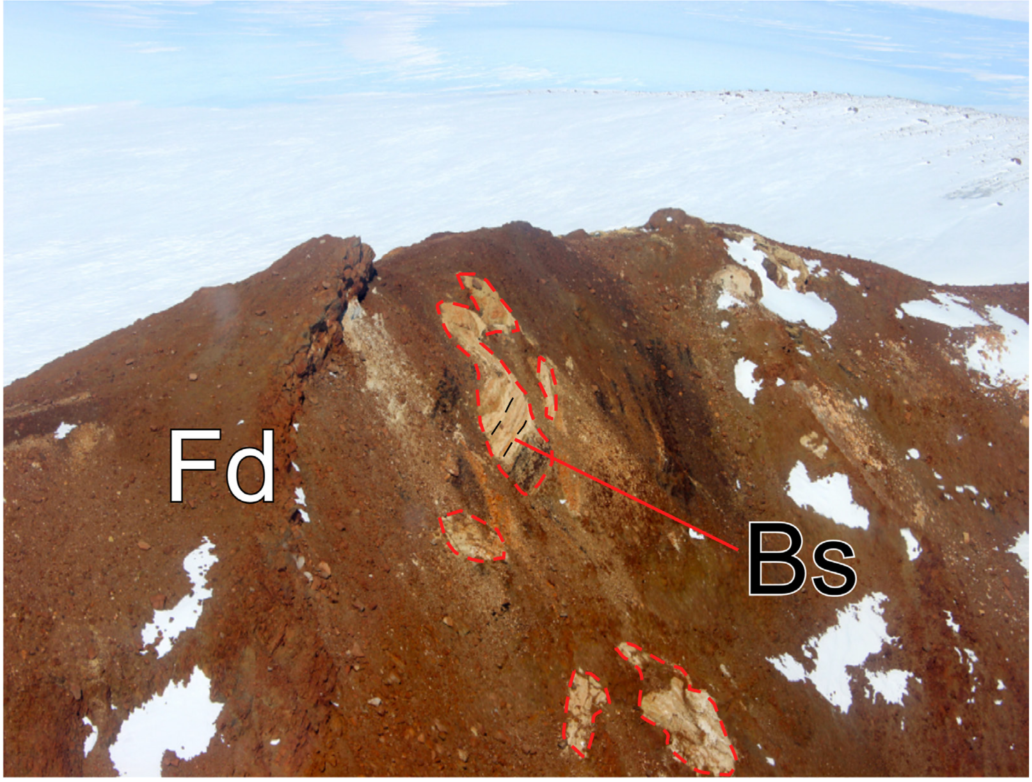

Fig. 6 - Bodies of Beacon sandstone (Bs) with inclined strata (black dashed line), floating within the Ferrar Dolerite (Fd) in the Reckling Peak area.

at an unnamed nunatak SE of Beckett Nunatak (Fig. 7), and at Reckling Peak, but no age-related macrofossils were found so far. Results of palynostratigraphic analyses indicate that the age span of the Beacon Supergroup deposits here ranges from at least Middle Triassic in the low-lying outcrops in the East (assemblages with abundant *Aratrisporites* from south of Beckett Nunatak) to as young as earliest Jurassic at higher elevations in the west (*Classopollis*-dominated assemblages at McLea Nunatak; Unverfärth et al., 2020). Such results suggest that both outcrops pertain to the Victoria Group, though from different stratigraphic levels.

Elsewhere it was impossible to further differentiate between Taylor and Victoria groups; as a result most of the Beacon rocks were mapped as Undifferentiated Beacon sandstone (Bs).

Sediments of the Beacon Supergroup generally display a horizontal or shallowly inclined bedding but in a few places the Beacon strata are tilted by the emplacement of the magmatic Ferrar rocks, e.g., at Reckling Peak.

Several sedimentary structures are present within Beacon rocks. Large tabular or trough-cross-bedded stratification is commonly present in sandstones. Both fine-grained sandstone and siltstone at bed tops commonly show ripple marks and occasional mud-filled desiccation cracks that testify to periods of sub-areal exposition. In some outcrops, soil marks such as flute casts are present, and, in some places, beds display syn-sedimentary deformation and slumping; trace fossils occur as well.

Ferrar Volcanic Suite

Ferrar Dolerite (Fd)

Ferrar Dolerite (Elliot et al., 1997) is the dominant rock-type in the area, and constitutes most parts of Beckett Nunatak, Mt Armytage, Shultz Peak, and Trinity and Jarina nunataks; it also occurs at the top of the Kirkwood Range and at Mt Smith. In the southern part of the mapped area the Ferrar Dolerite crops out mainly in the Convoy Range. It consists of tholeiitic dolerite sills and minor dykes. A K/Ar whole-rock isochron of 174 ± 10 Ma (Tab. I) has been reported for Ferrar Dolerite from the Mt Murchison quadrangle (Brotzu et al., 1988), whereas Fleming et al. (1997) indicate a $^{40}Ar/^{39}Ar$ age of 176.7 ± 8 Ma (on feldspar and biotite) for the Ferrar tholeiitic rocks as a whole.

More recent age data (U/Pb on zircon) for both intrusive and extrusive Ferrar magmatism (Tab. I) cluster tightly around 182 Ma (Elliot et al., 2021).

Ferrar Dolerite sills typically show columnar jointing (Fig. 8A) and in places enclose large rafts of the surrounding host rocks. Sills range from fine-grained, with chilled margins against adjacent rocks to coarse-grained with doleritic to subophitic texture; minor granophyre and pegmatitic facies also occur.

At Mt Smith the dolerite has been emplaced over the Kukri Erosion Surface with the occasional interposition of small bodies of Beacon sandstone. Minor dykes are emplaced also in the underlying granitic basement (Fig. 3B; Capponi et al., 2020).

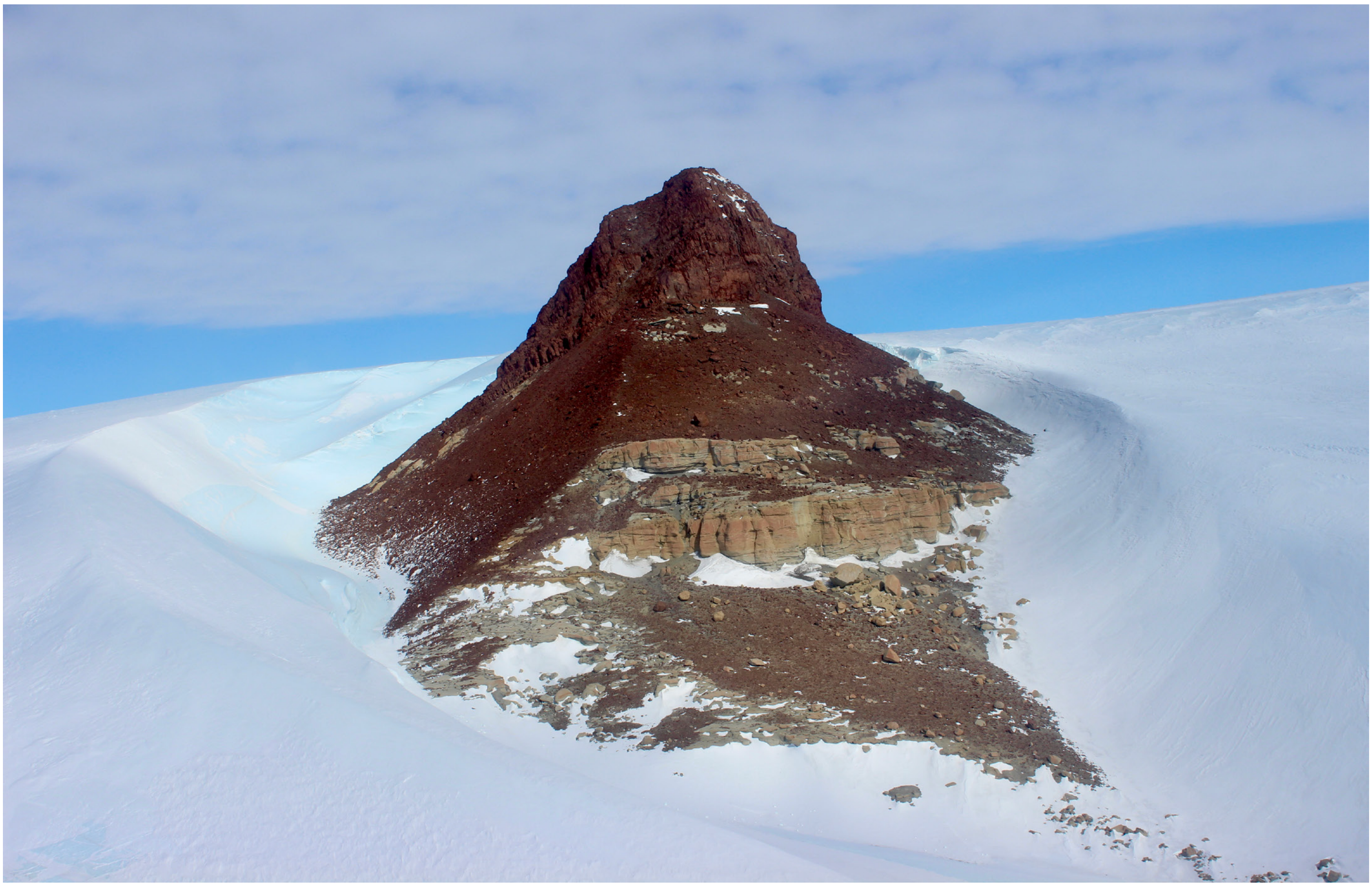

Fig. 7 - The nameless nunatak SE of Beckett Nunatak.

South of Mt Chetwynd, the dolerite has been emplaced above a level of Beacon sandstone that is continuous for about 1 km (see above). Here, the Beacon sandstones overlie the Granite Harbour granitoid, but the erosion surface is not exposed.

In the Kirkwood Range, the Ferrar sills are emplaced on the erosion surface with no interposition of any Beacon sandstone. Elsewhere the base of the Ferrar sills is not exposed.

Mawson Formation (Mf)

In the north-western part of the quadrangle the Mawson Formation (Ballance and Watters, 1971; equivalent to the Exposure Hill Formation, Elliott and Hanson, 2001) is exposed at Battlements Nunatak and at Reckling Peak, but such outcrops are limited compared with large outcrops present in the Allan Hills and Mt Brooke - Coombs Hills area. The relationships with the overlying Kirkpatrick Basalt are preserved at Battlements Nunatak and Carapace Nunatak. Borns and Hall (1969) firstly recognised the volcanic origin of the rocks of the Mawson Formation. The most abundant lithologies are massive, unsorted to poorly sorted lapilli tuff and breccia, often with clasts and rafts of Beacon sediment (Fig. 8B). Sandstone (Fig. 8C) and siltstone with associated basaltic lavas also occur. Such lithologies were interpreted as a debris avalanche that slumped off a phreatomagmatic vent wall (Reubi et al., 2005; Cox et al., 2012), overlain by pyroclastic deposits that retain evidence of their constructional landforms (Ross et al., 2008). Cementation by quartz and zeolites is pervasive. The Mawson Formation is cut by basalt dykes and large tuff-filled clastic dykes.

Kirkpatrick Basalt (Kb)

The basalt flows of the Kirkpatrick Basalt (Kb) are limited to small outcrops at Reckling Peak, in the eastern part of the Battlements Nunatak, very small outcrops at McLea Nunatak, at Carapace Nunatak and at Mt Brooke. They consist of columnar jointed basalt associated with red, palagonitised hyaloclastite, including both complete and fragmented basaltic pillows. Intercalated lenses of Mawson Formation and volcaniclastic intervals of tuff and lapilli tuff occur.

Whole-rock K/Ar dates from the Mesa Range basalts (Mt Murchison quadrangle) indicate 178 Ma as minimum age for the whole lava sequence (Elliot and Foland, 1986). A whole rock $^{40}Ar/^{39}Ar$ age of 174.2±1 Ma was obtained by

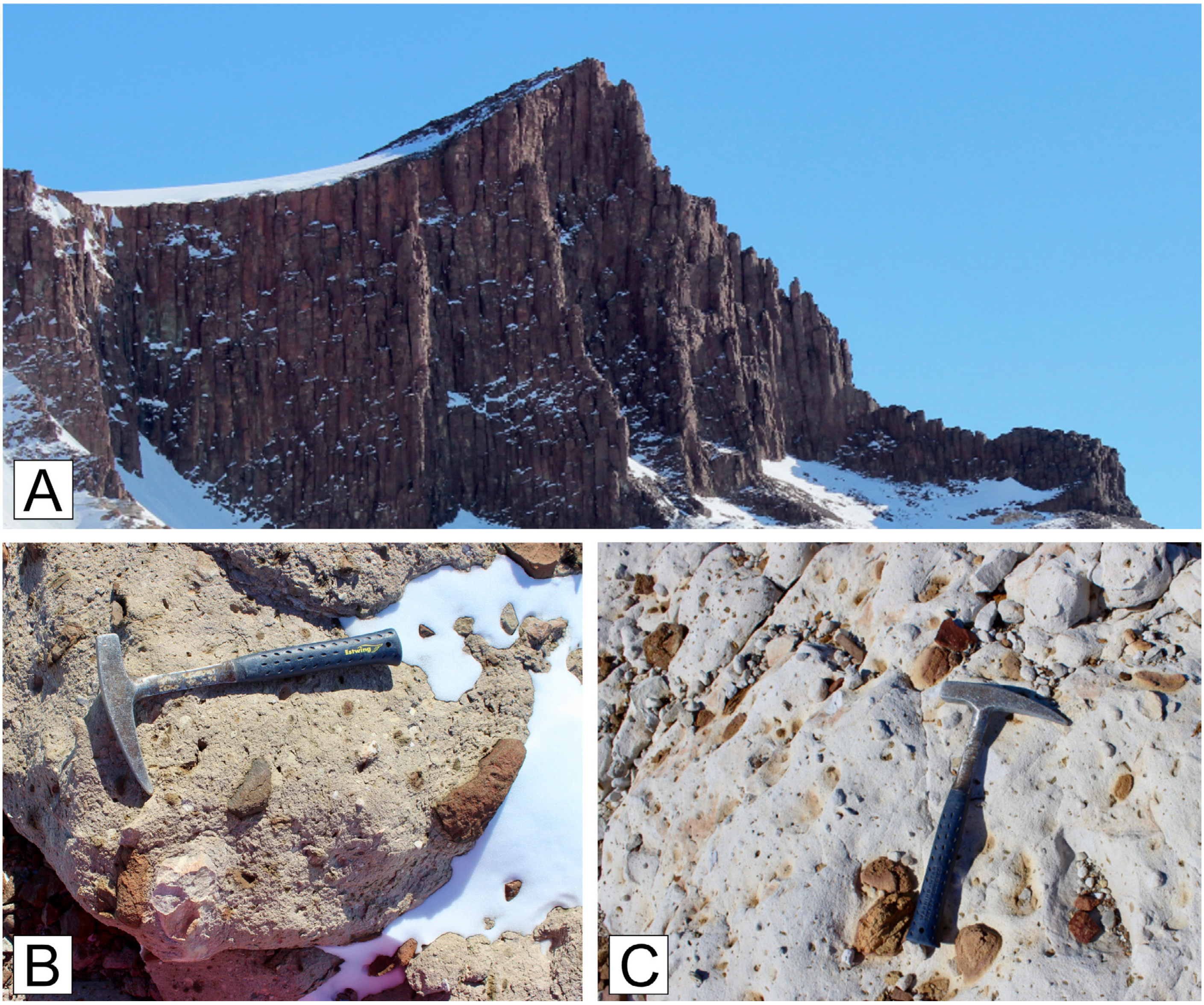

Fig. 8 - A) Columnar jointing of the Ferrar Dolerite at the top of Mt Smith; B) appearance of the Mawson Formation in the Reckling Peak area. Clasts and rafts of Beacon sandstone are present; C) outcrop appearance of sandstone belonging to the Mawson Formation in the Reckling Peak area.

McIntosh et al. (1986). More recent age data cluster around 182 Ma (Elliot et al., 2021).

Glacial and Quaternary deposits

Glacial and Quaternary deposits in the northern sector of Convoy Range and Franklin Island quadrangles were grouped for mapping purposes into: supraglacial till moraine (us); glacial drifts (mt, ui2, ui, ut, ui1, ul); beach and stranded marine deposit (ub) and colluvium, scree and regolith (uc). Glacial drifts are related to both ice sheets and local glaciers.
The **older undifferentiated till (mt)** is used here to classify eroded remnants and scattered plagues of glaciogenic sequences found throughout the Transantarctic Mountains. The drift includes highly weathered semi-lithified diamictons or lodgement tills, with some fluvioglacial and glaciolacustrine interbeds of sand, conglomerate and pebbly silt (Sirius Group: Mercer 1972; McKelvey et al. 1991; Ricker Hills Tillite in the Mt Joyce area, Baroni et al., 2008), and scattered moderately weathered to highly weathered bouldery sandy drift (mapped in the Allan and Coombs hills). The undifferentiated till is correlated with the Sirius Group, which has been interpreted as deposits of multiple glaciations within different wet-based ice sheet drainage systems during the Miocene-Pliocene, but potentially also contains material of Oligocene age.
The **older ice sheet till (ui2)** is referred to the *Convoy 2 Drift*, previously known as Alatna Valley B1 till (Calkin, 1964) or Ross Sea II till (Pocknall et al., 1994).

This unit was described in the Convoy Range, at 1100-1300 m elevation in Towle and Northwind valleys. The poorly sorted, bouldery sandy till contains dolerite and erratic granitoid boulders and post-dates local glacier tills from lobes of overriding plateau ice. The inferred age is Pliocene-Pleistocene.
The **undifferentiated ice sheet margin till (ui)** outcrops in several places and is well represented at Mt Murray (Fig. 9), Mt Armytage and Beckett Nunatak. These till deposits consist in clast- to matrix-supported diamicton, ranging in size from boulder to sand, generally unweathered to slightly weathered. On the basis of landform and location with regard to ice sheets, this undifferentiated material is interpreted to range in age from Late Pliocene to Holocene.
The **undifferentiated till (ut)** is widespread all over the area. This unit has been mapped where the origin and age of the deposits are unknown, although landforms and/or degree of weathering suggest a relatively young Quaternary age.
The **younger ice sheet till (ui1)** is referred to the *Convoy 1 Drift*, previously described as Alatna Valley B2 till (Calkin, 1964) or Ross Sea I till (Pocknall et al., 1994). The reference area is in the northern part of Convoy Range, where it crops out at 800-1100 m in elevation in Towle and Northwind valleys. Deposited by ice lobes flowing toward the west, the poorly sorted bouldery sandy till is locally ice-cored and contains dolerite and erratic granitoid boulders. The inferred age is Middle to Late Pleistocene.
The younger and older ice sheet tills (ui1 and ui2) are interpreted as the result of ice thickening and development of a piedmont glacier or dome in the Benson-Fry-Towle glacier area (Cox et al., 2012). The drift post-dates local glacial tills deposited by plateau ice that overflowed the Ferrar Dolerite escarpment into valley heads from the west, but their age is otherwise poorly understood (Calkin, 1964).
There are **undifferentiated local glacier till (ul)** deposits located in few sites, which seem to be relatively young,

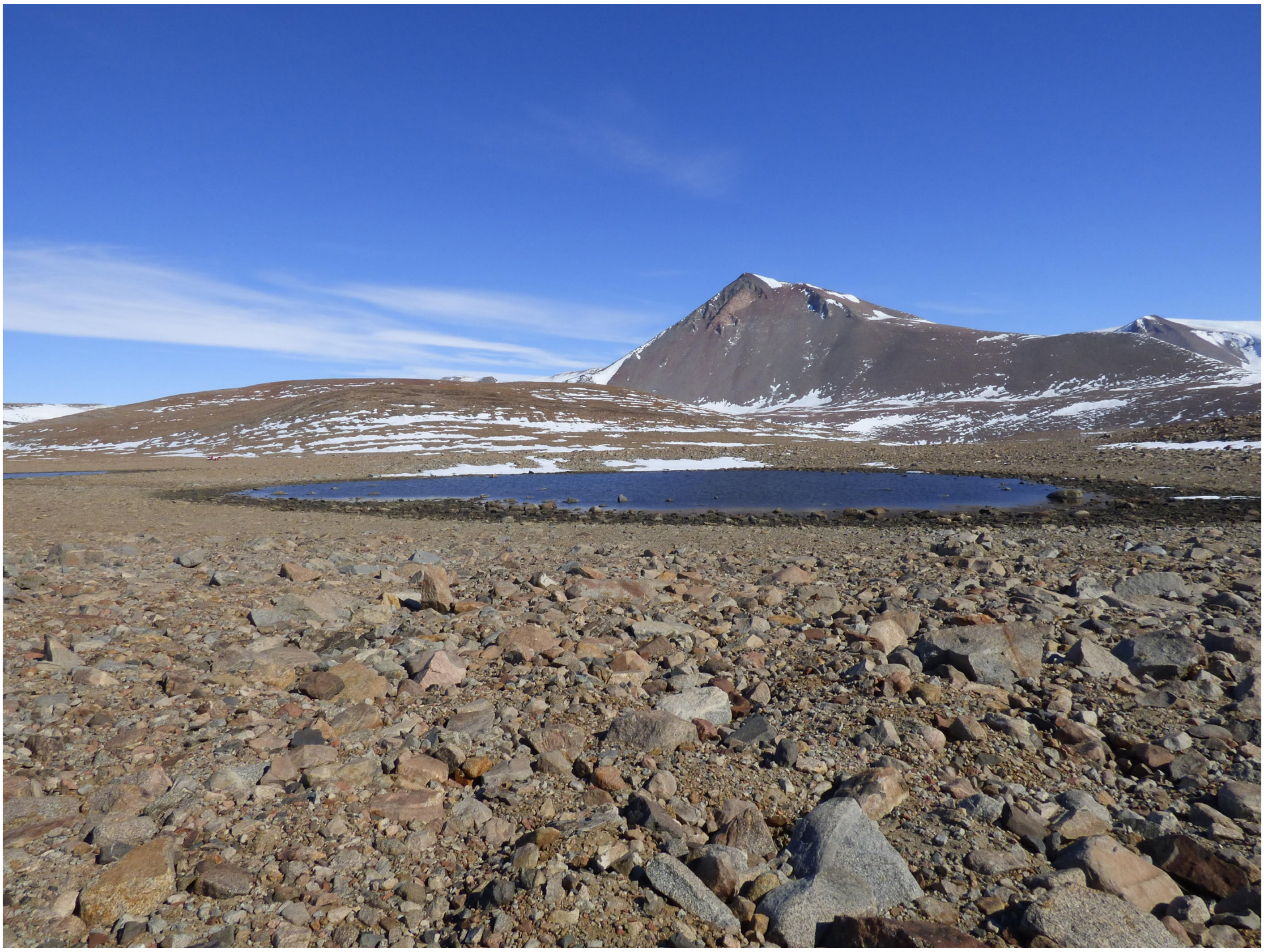

Fig. 9 - Mt Murray view from SE. In the foreground undifferentiated ice sheet margin till (ui); in the background, Mt Murray eastern slope, covered by scree. The ridge behind the lake is covered by a thick blanket of regolith.

considering the proximity to local glaciers (Holocene), and **supraglacial till (us)** is common at the foot of slopes bordering active glacial ice. At several locations, supraglacial till forms shear or confluence moraines, being particularly evident in areas affected by ablation induced by wind (blue ice area). Holocene bedrock physical disintegration on slopes produces deep **colluvium, regolith and scree slope deposits (uc)**, which range in size from clast-supported angular boulders to finer gravel and sand, depending on bedrock lithology and weathering processes. These deposits are remobilised by creep and gelifluction processes, as well as by patterned ground (Pleistocene-Holocene).
Holocene beaches and stranded marine deposits (ub) are present in Charcot Cove, to the north-west of Bruce Point. They mainly consist of sand, gravel and pebbles, up to well-rounded blocks, being similar to those found to the south (Depot Island, Cape Ross and Gregory Island), but less extended.

TECTONICS

Ross Tectonics

The effects of the Ross deformation are limited to the development of the tectonic foliation that can be observed in the rare slivers of the Wilson Terrane schist. Both at Mt Murray and at the eastern slopes of Mt Endeavour, such tectonic foliation is steeply dipping to the ENE (Fig. 10A), but the folds exposed in the southern slopes of Mt Murray clearly indicate a structural control on the attitudes of the Wilson rocks (Capponi et al., 2020). In the Mt Murray outcrop, a mineral lineation lies on the foliation and is steeply plunging to the ENE. Two foliations have been observed at the microscale in metasandstones sampled at Mt Murray: an older fine continuous foliation and a later gradational crenulation cleavage (foliation classification according to Passchier and Trouw, 2005). Dynamic recrystallization of biotite, muscovite and quartz is associated to the older foliation, whereas no recrystallization occurred along the crenulation cleavage. Another sliver at Mt Murray is made by a biotite-bearing paragneiss that shows a fine continuous foliation highlighted by the grain shape preferred orientation of dynamically recrystallised biotite and quartz crystals (Fig. 11).
Another result of the Ross tectonics is the weak foliation that locally affects the Granite Harbour granitoids.
On the base of the NE-SW strike of the sub-vertical Irizar and Vegetation dykes, Rocchi et al. (2009) suggested a NW-SE extension during the latest stages of the Ross Orogeny.

Post-Ross Tectonics

The most striking feature related to the post-Ross tectonics is represented by the regional unconformity along the pre-Beacon erosion surface. This surface is the equivalent to the Kukri Peneplain as defined in the Dry Valleys (Barrett et al., 1986) and testifies to the uplift and erosion of the Ross Orogen; this surface represents a gap of about 80 to 100 Ma (Gunn and Warren, 1962; McKelvey et al., 1977; Cox et al., 2012). In the northern part of the quadrangles, this erosion surface is near-horizontal and it is visible at Mt Smith, Mt Gauss, Mt Murray, Mt Chetwynd and at the eastern slopes of Mt Endeavour (Capponi et al., 2020).
The elevation of the erosion surface varies from around 1200 m at Mt Endeavour, 1100 m at Mt Chetwynd and Mt Gauss, around 1000 m at Mt Murray and approximately 1300 m at Mt Smith. In the southern part of the map, a similar situation is present in the Benson Glacier area where a difference of about 200 m in the elevation of the erosion surface is recognised across the glacier, between the Mt Razorback area and Mt Perseverance area, with the latter about 200 m lower.
The origin of variation in the height of the erosion surface is not entirely clear. It may be due to original change in relief of the surface itself, related to differential erosion of the Cambrian-Ordovician basement. Alternatively, it could reflect post-Kukri activity of faults with hundreds of m of vertical offset (Cox et al., 2012; Capponi et al., 2020). Due to the extensive ice coverage, no field evidence of fault offset, either vertical or horizontal, has been found.
The outcrops of Beacon sandstone exposed at the unnamed nunatak SE of Beckett Nunatak and at McLea Nunatak are relatively close (about 16 km) and at similar altitude; despite this, they pertain to different stratigraphic levels, i.e., Triassic vs Lower Jurassic, respectively. Though not evident in the field, this suggests the occurrence of a fault with hundreds of m of vertical offset between the two outcrops. However, a disruption of the Beacon stratigraphy by the emplacement of the Ferrar Dolerite cannot be ruled out.
Beacon strata are generally sub-horizontal or shallowly dip both towards the W to NW and to the S to SW with very low angle (Fig. 10B); no evidence of regional deformation is present. There are, however, variations in the angle of dip that appear to be local (e.g., at Reckling Peak), due to the local deformation caused by the emplacement of the Ferrar Dolerite.
Minor faults, affecting the Granite Harbour granitoid, have been observed at Mt Chetwynd, in the northern part of the Kirkwood Range, and at Walker Rocks, in the central sector of the study area. In the Mt Chetwynd area, faults strike mostly E-W and dip at medium angle both toward

the N and the S (Fig. 10C), suggesting the occurrence of two systems of conjugated faults. Striae along N-dipping faults plunge toward the NW at medium angle (Fig. 10D); no striae were observed on S-dipping faults. On one fault of the S-dipping system, we observed dark domains with a shape typical of injection veins, revealing the possible occurrence of pseudotachylite (Capponi et al., 2020).

At Walker Rocks, two systems of faults have been recognised: one system strikes NE-SW and the other one strikes NW-SE (Fig. 10C). Faults belonging to the first system are sub-vertical or steeply dipping towards the SE or NW; faults of the second system dips at medium angle toward the NE; ultracataclasites are associated to both fault systems. Striae along fault surfaces generally plunge at low angle towards the NE and only in places they are steeply plunging towards the S to SE (Fig. 10D).

At Shoulder Mountain (southern Kirkwood Range), cm-thick layers of cataclasites (Fig. 12A) and protocataclasites (Fig. 12B) crosscut the Granite Harbour granitoid.

CONCLUSIONS

The integration of new detailed geological mapping, structural and petrographic analyses with previous mapping by Cox et al. (2012) allows a full coverage of the Convoy Range and Franklin Island USGS quadrangles, filling the gap between the GIGAMAP program (to the

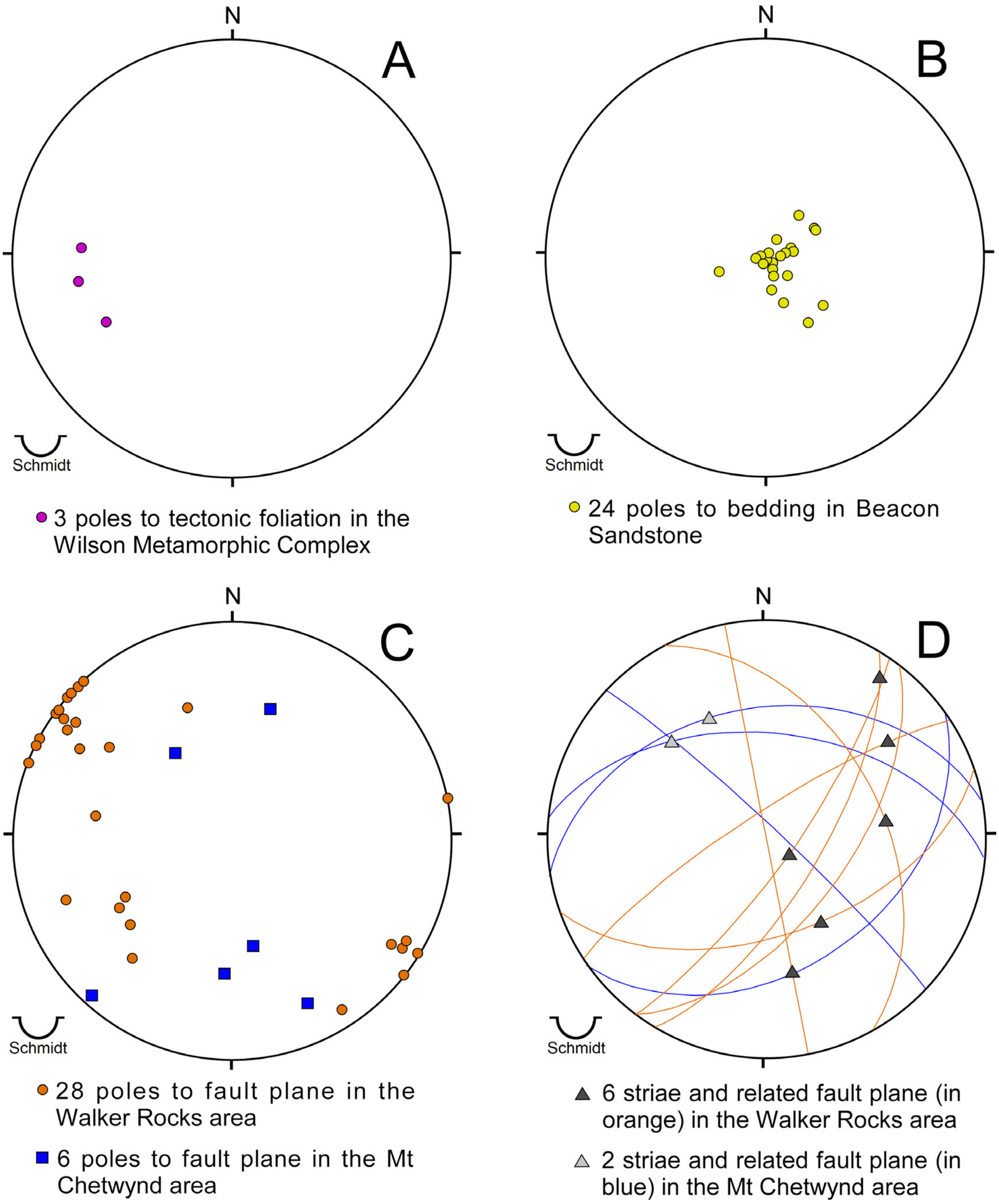

Fig. 10 - Equal area projection (lower hemisphere) of: A) poles to foliation in the Wilson Metamorphic Complex; B) poles to bedding in Beacon sandstone; C) poles to fault planes in the Walker Rocks and Mt Chetwynd area; D) striae and related fault planes in the Walker Rocks and Mt Chetwynd area.

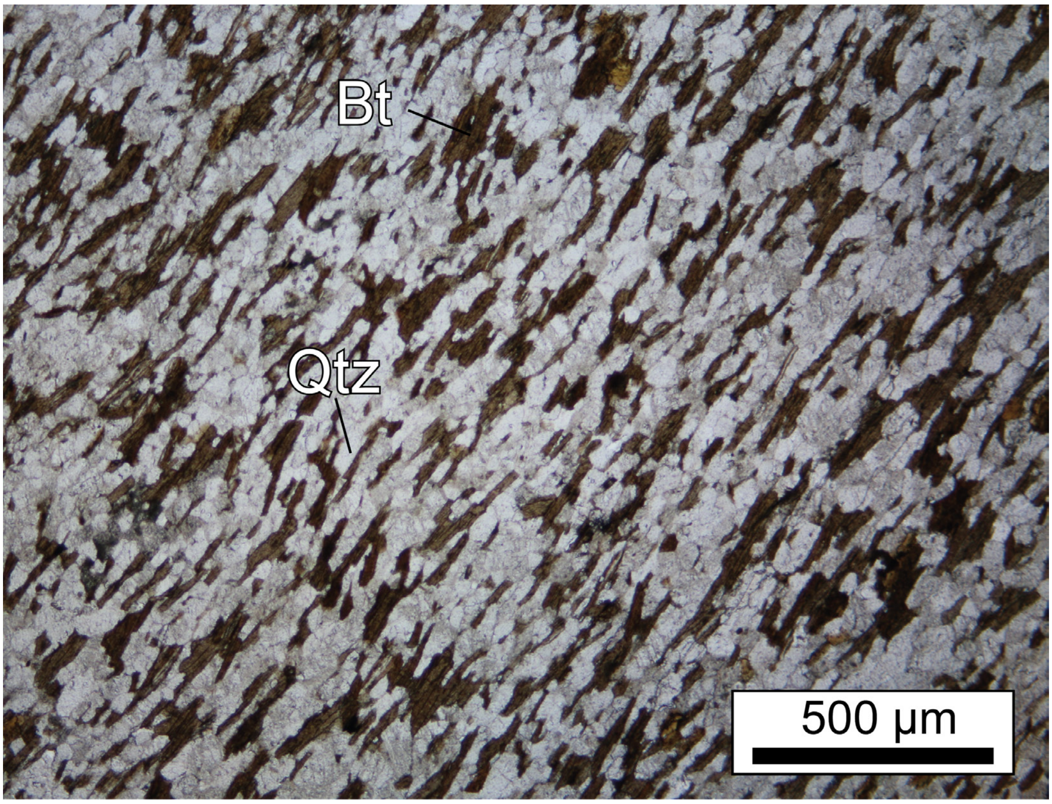

Fig. 11 - Microscopic aspect of the fine continuous foliation developed in biotite-bearing paragneiss cropping out at Mt Murray (Bt: biotite; Qtz: quartz) (Parallel Nicols).

north) and the maps by the New Zealand Antarctic program (to the south) and completing the coverage of Victoria Land; this work enabled to highlight some key features of this region.

Rocks of the Wilson Metamorphic Complex are scarcely exposed in this area, since they are restricted to small bodies and slivers within the granitoid of the Granite Harbour Intrusive Complex.

Microgabbro-microdiorite belonging to the Granite Harbour Intrusive Complex is present in the northeastern part of the mapped area. At the outcrop scale, these are very similar to the Ferrar Dolerite and the occurrence of gradational contacts with the granite, where present, is a key feature to distinguish such rocks.

Unlike in the southern part of the area, the occurrence of sedimentary rocks of the Beacon Supergroup is very

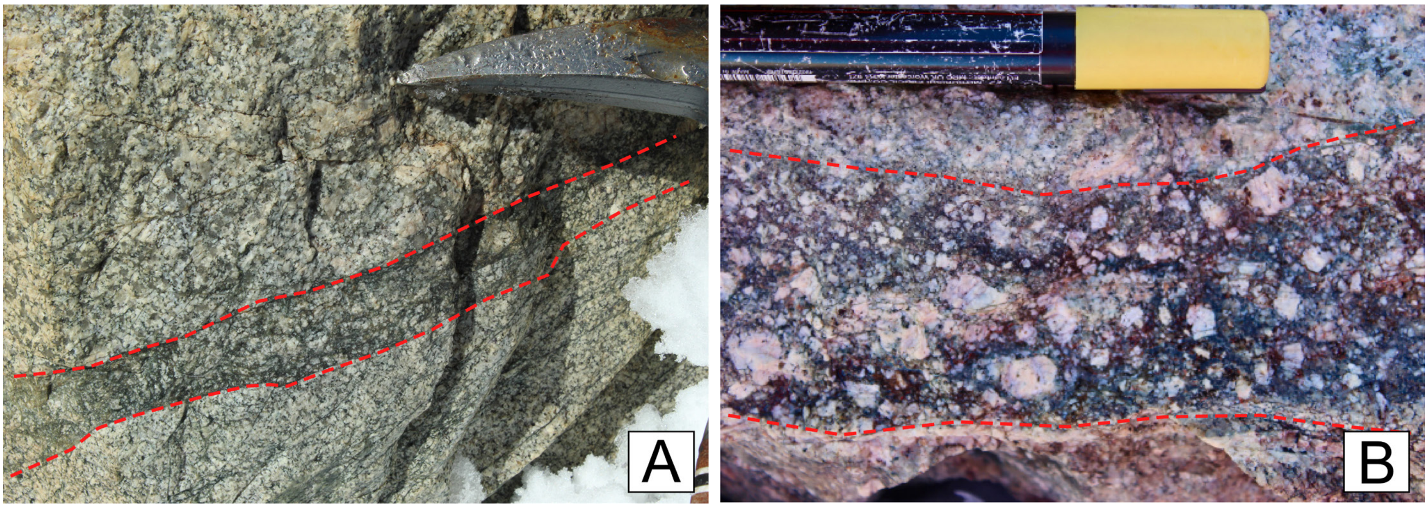

Fig. 12 - A) Cm-thick cataclasite crosscutting the Granite Harbour granitoid in the Shoulder Mountain area (southern Kirkwood Range); B) cm-thick protocataclasite crosscuting the Granite Harbour granitoid in the Shoulder Mountain area (southern Kirkwood Range).

limited in the northern sector of the map. Here, because of the small outcrops and the absence of age-diagnostic macrofossils, it is often impossible to specifically assign the Beacon sediments to either the Taylor or Victoria groups; all so-far obtained palynostratigraphic data, however, indicate Triassic and Early Jurassic ages.
The new mapping, combined with previous data, highlights some differences in the elevation of the Kukri Erosion Surface. Changes in the height of the erosion surface can be due to differential erosion or to the activity of subsequent faults with offset. The new map can be used as the starting point for any future geological investigation of the region.

SOFTWARE

The topographic Base was assembled with the software Qgis 2.18 and the map final layout was prepared with Adobe Illustrator CC 2018.

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