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Late Ross-Orogenic Deformation of Basement Rocks in the Northern Deep Freeze Range, Victoria Land, Antarctica: the Lichen Hills Shear Zone

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Abstract: Kinematic data from the basement rocks exposed at Lichen Hills in the upper Rennick Glacier, northern Victoria Land, indicate the presence of an intra-Wilson Terrane late Ross-orogenic high-strain reverse shear zone. ENE directed ductile shearing and WSW-directed late-stage brittle reverse faults overprint metasedimentary rocks and thick leucogranites of the Granite Harbour Intrusives. The Ross-orogenic age of the structures is attested by the involvement of leucogranites in ductile shearing and cross-cutting relationships between younger aplitic dykes and brittle deformations. This structural pattern strongly supports a relationship between the Lichen Hills Shear zone and the Wilson Thrust in Oates Land, the eastern branch of a late-Ross bivergent high-strain thrust system. Post-Ross structures are represented by reverse off-sets of the – in this area – Triassic to early Jurassic Beacon strata that are probably related to volcanotectonic events during Ferrar intrusion and the Cenozoic development of NW-SE striking dextral faults and N-S striking large-scale normal faults that parallel the Rennick Glacier.

Zusammenfassung: Das Grundgebirge des Wilson-Terranes in den Lichen Hills im oberen Rennick Glacier im Nordvictorialand enthält mächtige spät-ross-orogenetische hochduktile aufschiebende Scherzonen. Eine ENE–gerichtete duktile Scherung des hangenden Blockes und entgegen gesetzte spätere spröde Aufschiebungen überprägen dort Metasedimentgesteine und mächtige Leukogranite der Granite Harbour Intrusiva. Das ross-orogenetische Alter der Deformation ist dadurch belegt, dass die Leukogranite von den duktilen Strukturen betroffen sind, diese aber von jüngeren aplitischen Gängen geschnitten werden. Das gesamte Erscheinungsbild legt nahe, dass die Lichen-Hills-Scherzone ein Teil der Wilson-Überschiebung in Oates-Land ist. Diese stellt den östlichen Ast eines spät-ross-orogenetischen, zweiseitigen Überschiebungsgürtels dar. Post-ross-orogenetische Strukturen sind aufschiebende Versätze der – in dieser Region – triassisch bis frühjurassischen Beacon-Sedimentgesteine, welche auf eine mögliche Vulkanotektonik während des Ferrar-Ereignisses zurückzuführen sind, und känozoische NW-SE streichende dextrale Störungen und Rennickgletscher-parallele N-S streichende große Abschiebungen.

INTRODUCTION

Northern Victoria Land is located at the Pacific Southern Ocean termination of the Transantarctic Mountains (TAM), which cross the Antarctic continent for more than 3000 km. Its front represents the uplifted western shoulder of the Cenozoic West Antarctic Rift System (WARS), one of the largest continental rifts worldwide. This younger, rift-related history complicates our understanding of the older orogenic evolution, which manifested during the Late Proterozoic to Early Palaeozoic Ross Orogeny (Fig. 1).

The Ross Orogen is an Andean-type system that was associated with west to southwest-directed subduction of the Palaeo-Pacific Ocean under East Gondwana. Initiation of subduction is indicated by metamorphism and granitic plutonism in the latest Neoproterozoic leading to the transformation of the former passive into an active continental margin. This active margin is generally referred to as the Wilson "Terrane" (KLEINSCHMIDT & TESSENSOHN 1987) or Wilson Mobile Belt (ROLAND et al. 2004). Accretion of the Middle Cambrian intra-oceanic Bowers island arc (Bowers Terrane) to this margin occurred in the late Middle Cambrian, with the collision initiating: (i) the uplift and exhumation of HP and UHP metamorphic rocks along the Wilson-Bowers suture zone; (ii) the collapse of the Wilson Mobile Belt units and (iii) the migration of the subduction zone outwards resulting in the formation of the Late Cambrian-Ordovician Robertson Bay Accretionary Wedge (or Robertson Bay "Terrane").

The Wilson Mobile Belt dominantly consists of medium- to high-grade metamorphic rocks (schists, gneisses, migmatites) and widespread syn- and late-orogenic plutonic rocks. Syn-orogenic plutonism is mainly dated to 550-520 Ma (e.g., ENCARNACIÓN & GRUNOW 1996, BASSETT et al. 2002, GOODGE 2002 cum lit.). Late-orogenic plutonism associated with the Granite Harbour Intrusive Complex have emplacement ages in the range of 520 to 480 Ma (e.g., GOODGE 2002 cum lit.). In addition to the medium- to high-grade metamorphic rocks, the Wilson Mobile Belt contains a series of low-grade metasedimentary rocks (the Rennick Schists, Berg Group, or Priestley Formation; GANOVEX TEAM 1987). The age relation of all these low-grade metamorphic rocks to the higher-grade constituents is still a matter of debate.

The Wilson Mobile Belt is also divided along a series of high-strain reverse shear zones that cut across and deform the late-orogenic and largely undeformed Granite Harbour Intrusives. These shear zones form continuous belts of frontal east-directed ductile thrusts and west-directed backthrusts that are referred to as the Wilson Thrust and the Exiles Thrust, respectively (FLÖTTMANN & KLEINSCHMIDT 1991, 1993, KLEINSCHMIDT 1992). Along these thrusts, deep-crustal metamorphic and magmatic units of the central Wilson Mobile Belt were detached and thrust east- and westward over the foreland and onto the Precambrian East Antarctic craton, respectively. Comparable mylonitic shear zones within Ross-orogenic intrusions were reported along both margins of the Campbell Glacier (e.g., DI VINCENZO et al. 2007 cum lit.) and in the area of the southern Daniels Range and Outback Nunataks (LÄUFER & ROSSETTI 2003, LÄUFER et al. 2006a). The age of thrusting is

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generally interpreted to be late Ross-orogenic and synchronous to the emplacement of the late-stage members of the Granite Harbour Intrusives.

The Ross-orogenic basement is also intruded by the mid-Palaeozoic Admiralty Intrusives, which comprise a suite of calc-alkaline granitic rocks (BORG et al. 1987, FIORETTI et al. 1997). High-level and subaerial equivalents of these plutonites are the Gallipoli Volcanics, which consist of dacites, rhyodacites, and andesites (e.g. GANOVEX TEAM 1987, FIORETTI et al. 2001). At Mt. Black Prince, these rocks are interlaid with plant fossil-bearing sedimentary rocks that unconformably overlay the

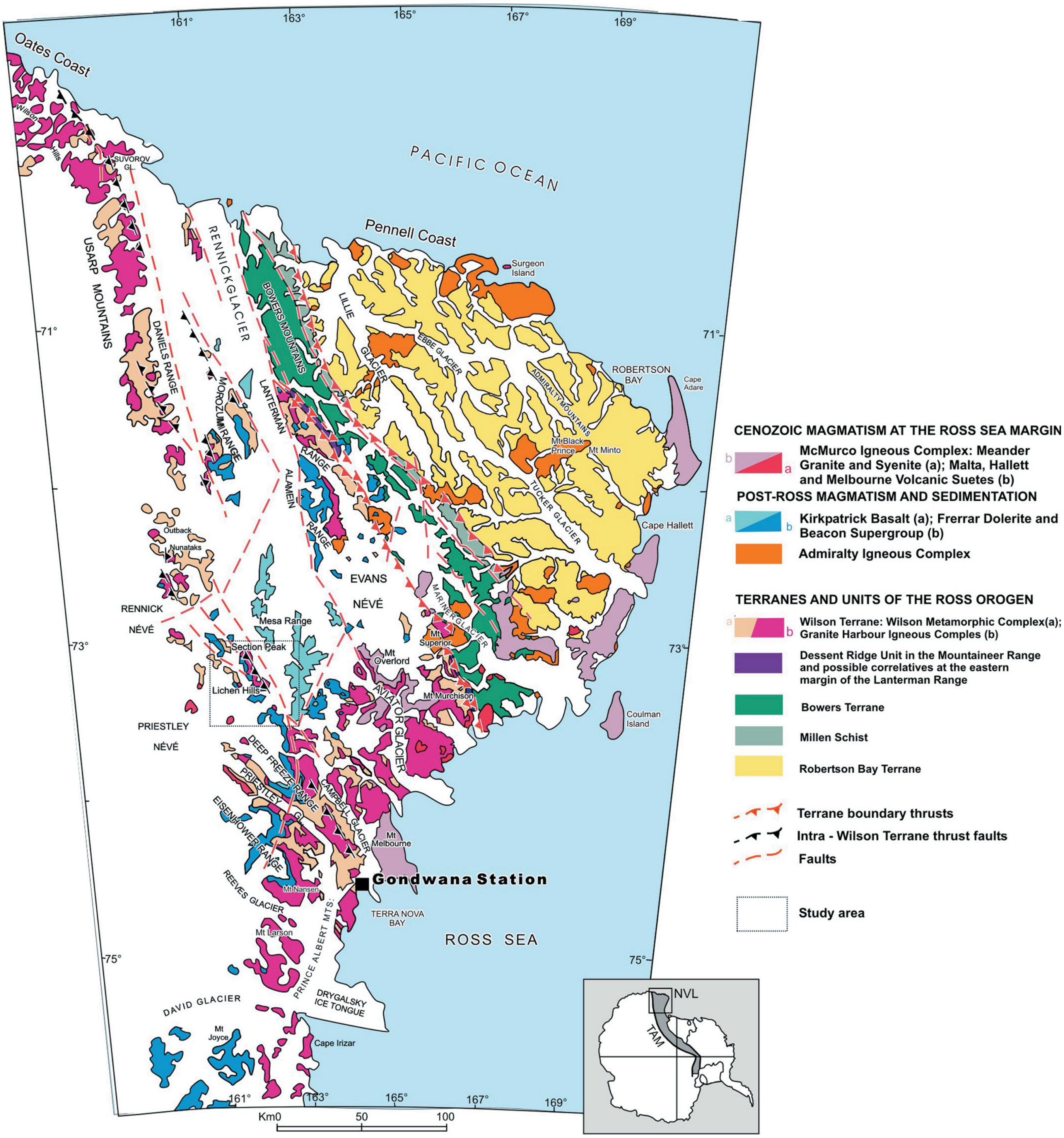

Fig. 1: Geological and tectonic sketch map of northern Victoria Land (NVL) indicating the terrane boundary thrust faults (in red) and known occurrences of late Ross-orogenic intra-Wilson Terrane ductile thrust faults (in black; see LÄUFER & ROSSETTI 2003 cum lit.) including the new occurrences described in this paper. Modified from the GIGAMAP series (e.g., LÄUFER et al. 2006b). Inset: TAM = Transantarctic Mountains.

Abb. 1: Geologische und tektonische Übersichtskarte des nördlichen Viktorialandes (NVL) mit den ross-orogenen Terrane-Grenzen (in rot) und bekannten Lokationen spät-ross-orogener intra-Wilson-Terrane duktiler Überschiebungen (in schwarz, s. LÄUFER & ROSSETTI 2003 cum lit.) inklusive der in dieser Arbeit beschriebenen neuen Vorkommen. Verändert nach Serie GIGAMAP (z.B. LÄUFER et al. 2006b). Inset: TAM = Transantarktisches Gebirge.

Admiralty Granites (Findlay & Jordan 1984). As the plant-fossils and granites are of roughly the same age, it is reasonable to assume that a phase of uplift coinciding with magmatism occurred in the mid-Palaeozoic (Tessensohn 1984).

The Ross-aged basement is furthermore unconformably capped by the sedimentary rocks of the Beacon Supergroup (Barrett et al. 1972), which were deposited in Permian to earliest Jurassic times. Devonian to Carboniferous units were also identified in the southern Victoria Land exposures of the Beacon Supergroup. The Beacon sedimentary sequence is intruded and covered by the Jurassic sills and lavas of the Ferrar Supergroup, which mark the onset of the initial break-up of the Gondwana supercontinent (e.g., Grindley 1963, Viereck-Götte et al. 2007).

The youngest rocks to crop out in the region are Cenozoic magmatic rocks that are related to the WARS and occur along the Ross Sea margin of northern Victoria Land (e.g., Rocchi et al. 2002).

In this paper, we report new kinematic information relating to the development of an east-directed branch of the aforementioned bi-vergent Exiles-Wilson thrust system outcropping at the Lichen Hills in the Deep Freeze Range of northern Victoria Land. This branch links the so far known occurrences of the Wilson Thrust from the Outback Nunataks further north (Läufer & Rossetti 2003) with genetically related reverse high-strain shear zones reported from the western margin of the lower Campbell Glacier further south by Castelli et al. (1989), Palmeri et al. (1989), Musumeci & Pertusati (2000), Di Vincenzo et al. (2007), and Rossetti et al. (2007). As a result, this dominant reverse thrust zone can be traced along strike from the Ross Sea in the south to the Pacific Southern Ocean in the north - thus defining a dominant orogen-scale structure.

REGIONAL GEOLOGY OF THE DEEP FREEZE RANGE

The Deep Freeze Range represents a NW–SE oriented mountain range located northwest of Terra Nova Bay between Priestley and Campbell glaciers to the southwest and north-east, respectivly (Fig. 1).

The Ross-orogenic basement of the Deep Freeze Range consists of medium to high-grade metamorphics that are intruded by the voluminous Granite Harbour Intrusive Complex. A medium- to high-grade monometamorphic unit (the Priestley Schists: cf. GANOVEX Team 1987 cum lit.) can

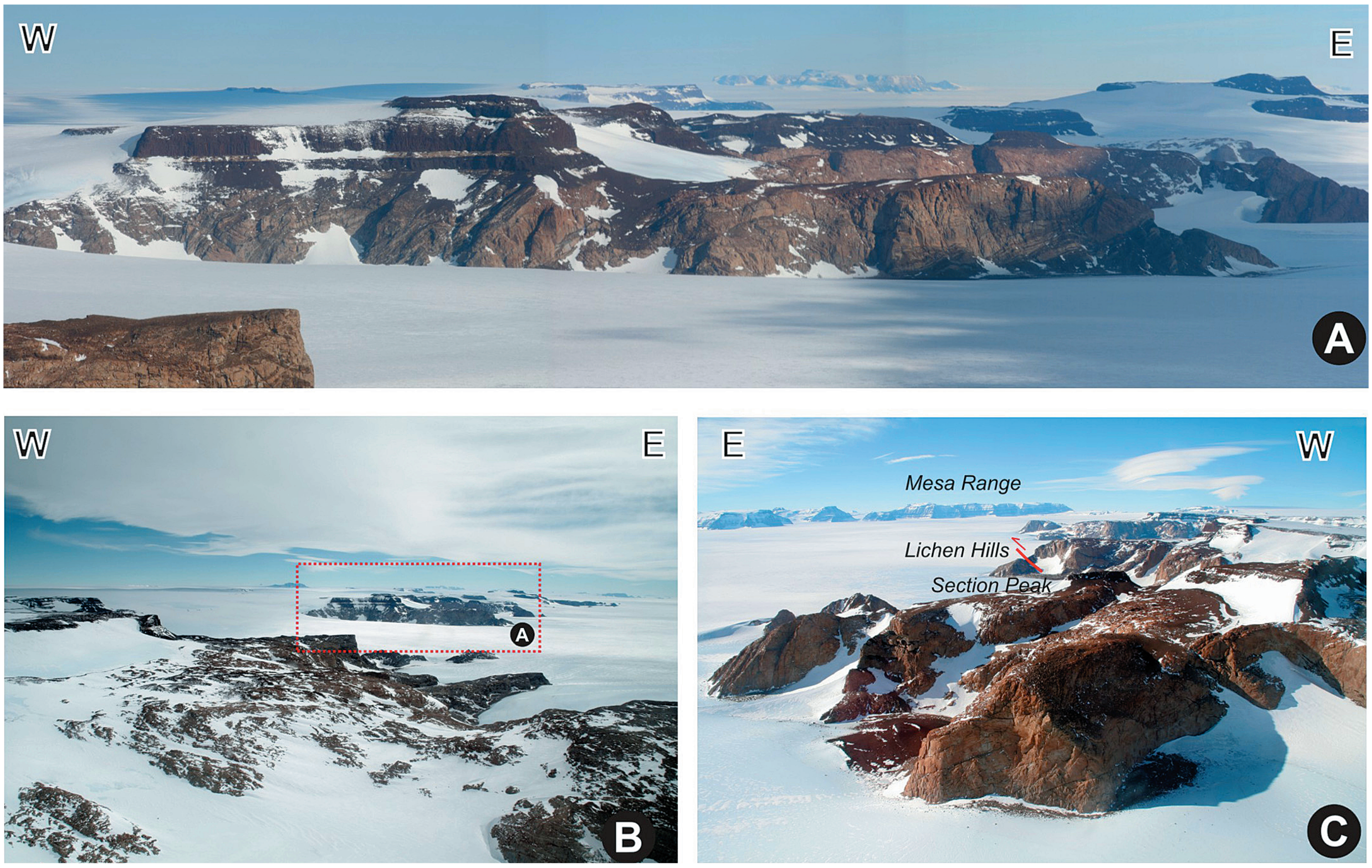

Fig. 2: (A) & (B) = The Lichen Hills Shear Zone. The Ross-orogenic basement consists of ductilely sheared leucogranites and schistose gneisses. Foliation and ductile shear planes dip towards the W. The Kukri erosion surface on top of the basement rocks forms the base of the post-Ross cover units of the Beacon and Ferrar formations. (C) = View from the north across Section Peak towards the Lichen Hills indicating the ductile shear zone in red. The Ferrar volcanics of the Mesa Range are visible in the background.

Abb. 2: (A) & (B) = Die Lichen-Hills-Scherzone. Das ross-orogene Grundgebirge besteht aus duktil zerscherten Leukograniten und Schiefergneisen. Die Foliation und duktilen Scherflächen fallen nach W ein. Die Kukri-Erosionsfläche am Top der Grundgebirgseinheiten bildet die Basis der post-orogenen Deckeinheiten der Beacon und Ferrar Formationen. (C) = Blick von N über Section Peak auf die Lichen Hills. Die duktile Scherzone ist in rot angedeutet. Die Ferrar-Vulkanite der Mesa Range sind im Hintergrund zu sehen.

be distinguished from a polymetamorphic complex consisting of high-grade gneisses and migmatites with relicts of granulites (TALARICO & CASTELLI 1995, MUSUMECI & PERTUSATI 2000). The Eisenhower Range, separated from the Deep Freeze Range by the Priestley Glacier, additionally contains low-grade metasedimentary units (e.g., the Priestley Formation (RICKER & SKINNER 1968). Particularly the central Deep Freeze Range represents an area where the transition from lower to higher metamorphic grades reaching granulite facies can be observed within a few kilometres only (e.g., TALARICO & CASTELLI 1995, PALMERI 1997). MUSUMECI & PERTUSATI (2000) describe NW–SE striking upright folds with well-developed axial planar cleavages and thrusts to be the main structural features in the area. According to these authors, the structural evolution involves progressive deformation with two main deformation phases. The metamorphic units are intruded by both synkinematic well foliated sheet-like intrusions and late-/postkinematic plutons and dykes.

A regional erosion surface – the Kukri Peneplain – of presumably Devonian age tops these granites and represents the base of the Beacon Supergroup sedimentary sequence (Fig. 2). They have been described in detail by SCHÖNER et al. (2007, 2011 this vol.). The strata immediately above the erosion surface comprise basal conglomerate consisting of pebbles of quartz, plutonic and metamorphic rocks derived from the underlying basement. The main parts of the Beacon sedimentary rocks above this conglomerate consist of light-coloured fluvial coarse-grained sandstones and siltstones interlayering with dark mudstones. Several occurrences of lake sediments yielding a fossil fauna and flora of Triassic to locally early Jurassic age have been identified. Generally, the sedimentary environment of the Beacon Supergroup was that of fluvial plains and braided river systems with local lakes covering the Gondwana supercontinent. The fossil remains indicate a warm climate during the early Mesozoic so-called super greenhouse period post-dating the Permo-Carboniferous icehouse climate that is indicated by glacial sediments of the Beacon Supergroup occurring along the central Rennick Glacier (e.g., in the western Lanterman Range). Thick sills and lavas of the Ferrar volcanics and Kirkpatrick basalts intrude or cover the Beacon sediments, respectively (VIERECK-GÖTTE et al. 2007). Locally, indications of phreatomagmatic events of early Jurassic age and soft-sediment deformation caused by the intrusion or extrusion of the Ferrar rocks into groundwater-rich sediments were reported. This indicates that the succession was very close or at the surface in early Jurassic times. Along Aviator Glacier at the eastern marging of the Deep Freeze Range, tephra and bombs of Cenozoic volcanics of the Mt. Melbourne Group cover the Palaeozoic basement; they are probably derived from the Mt. Overlord eruption centre close by. The geomorphology of the area is generally defined by a glacial plateau and terrace/escarpment-like appearance in contrast to an Alpine landscape east of the Rennick Glacier.

STRUCTURAL GEOLOGY AT LICHEN HILLS

Late Ross-orogenic deformation

The Lichen Hills form a part of the Frontier Mountains, which largely consist of massive, highly fractured leucogranitic bodies, partly folded pegmatite dykes, and aplite veins that intrude folded metasedimentary sequences of the Rennick Schists (STURM & CARRYER 1970, GANOVEX TEAM 1987). These schists are mainly fine- to medium-grained garnet-bearing biotite schists to schistose gneisses with abundant folded and boudinaged intrafolial mobilisates consisting of quartz ± feldspar ± garnet. Locally, nests of biotite are present within the schists and are possibly indicative of high fluid activity. The schists show strong ductile deformation and indications of simple shear. The massive leucogranites consist mainly of quartz, feldspar, biotite, muscovite, and garnet and form layers of different thickness within the schists. Apparently undeformed thin aplite dykes cross-cut both the shear fabric within the schists and the thick and weakly foliated leucogranites.

Structural investigations were carried out on the strongly strained metasedimentary rocks and the locally affected granitic rocks exposed at Lichen Hills. Kinematic analyses were performed by continuous tracing of penetrative crystal-plastic structures, orientation, and nature of structures. The non-coaxial component of strain was deduced from shear sense indicators in the XZ plane of the finite strain ellipsoid with the principal axes X > Y > Z. Kinematic indicators, such as S-C and shear band fabrics, rotated clasts, or intrafolial folds were used to account for tectonic transport directions (e.g., PASSCHIER & TROUW 1996).

Foliation planes (S_1) dip moderately (with angles of 30-65°) towards the west (Figs. 2 and 3). Stretching lineations (L1) are oriented WSW–ENE and are slightly oblique to the down-dip direction of the planes. Intrafolial folds within the schists as well as synthetically rotated clasts with σ-like geometries and a with respect to S_1 oblique foliation S_i in such clasts indicate top-to-ENE-directed reverse ductile shearing (Fig. 3). In parts, the leucogranites preserve a weak foliation that is defined by S_1-parallel alignment of mica and feldspar crystals, which dominantly manifests along the schist-granite boundaries and show shear band fabrics with top-to ENE directed kinematics. Thick leucogranitic injections within the plane of S_1 are stretched and boudinaged parallel to the stretching lineation L_1. They are rotated synthetically and form δ-clasts, ECC- and shear band-like fabrics, which are all again indicative of top-to-ENE-directed reverse simple shear.

The complete thickness of the deformation zone is hard to estimate. It can be observed along the whole exposed section of Lichen Hills between the Rennick Glacier in the east and the inland ice cover towards the west (see Fig. 2). A minimum thickness can thus be estimated to a few hundred metres. The whole section shows at least three zones of stronger deformation and different thicknesses defined by the schists, which are separated by the rather weakly but also foliated leucogranites. This indicates that strain was strongly partitioned depending on the physical behaviour and the contrasting competence of the two rock types.

Late stage brittle tectonics has affected the massive leucogranites in a way that moderately E-dipping fault planes are coated with white mica and show quartz fibre steps and Riedel shears that indicate late, opposite directed reverse faulting towards the W (Figs. 4 and 5). These may be interpreted as late-stage backthrust faults that facilitated uplift of the Wilson Mobile Belt during ongoing contraction at the Palaeo-Pacific Gond-

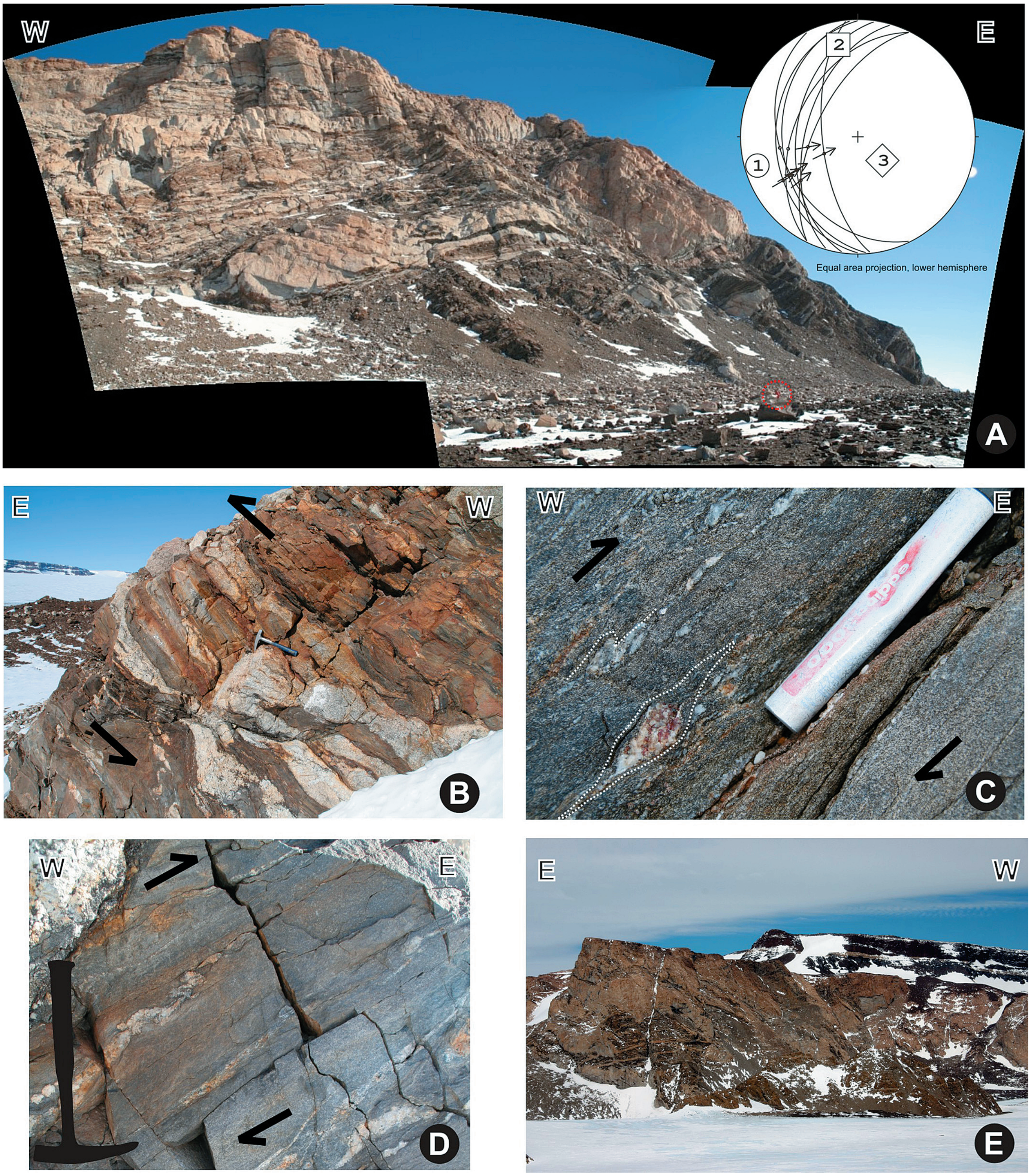

Fig. 3: Ductile structures of the Lichen Hills Shear Zone. (A) = Overview photo of the shear zone showing thick leucogranitic dykes and biotitic schistose gneisses at the northern side of Lichen Hills. The main foliation dips towards the W to WSW. The stereographic projection (lower hemisphere) shows foliation planes as great circles and mineral-/stretching-lineations and movement of the hanging wall block as arrows. Shear sense is top-to-ENE or -E. Numbers 1, 2, and 3 show the orientation of the main principle stress axes σ1, σ2, and σ3, respectively. (B) & (D) = Examples of shear sense indicators showing top-to-E or -ENE transport direction. (E) = The shear zone at the southern side of Lichen Hills with main foliation of the basement units dipping towards W to WSW. The basement is capped by post-Ross-orogenic Beacon and Ferrar rocks.

Abb. 3: Duktile Strukturen der Lichen Hills Scherzone. (A) = Überblicksfoto der Scherzone mit mächtigen leukogranitischen Gängen und biotitreichen Schiefergneisen auf der Nordseite der Lichen Hills. Die Hauptfoliation fällt Richtung W bis WSW ein. Die stereographischen Projektionen (untere Halbkugel) zeigt Foliationsflächen als Großkreise und Mineral-/Streckungslineationen mit Bewegung des hangenden Blockes als Pfeile. Der Schersinn ist Top-nach-ENE bis -E. Die Zahlen 1, 2 und 3 entsprechen der Orientierung der Hauptspannungsachsen σ1, σ2, and σ3. (B) & (D) = Beispiele für Schersinnindikatoren für Top-nach-E bis -ENE gerichteten tektonischen Transport. (E) = Die Scherzone auf der Südseite der Lichen Hills. Die Hauptfoliation fällt nach W bis WSW ein. Das Grundgebirge ist überlagert von den post-orogenen Beacon- und Ferrar-Gesteinen.

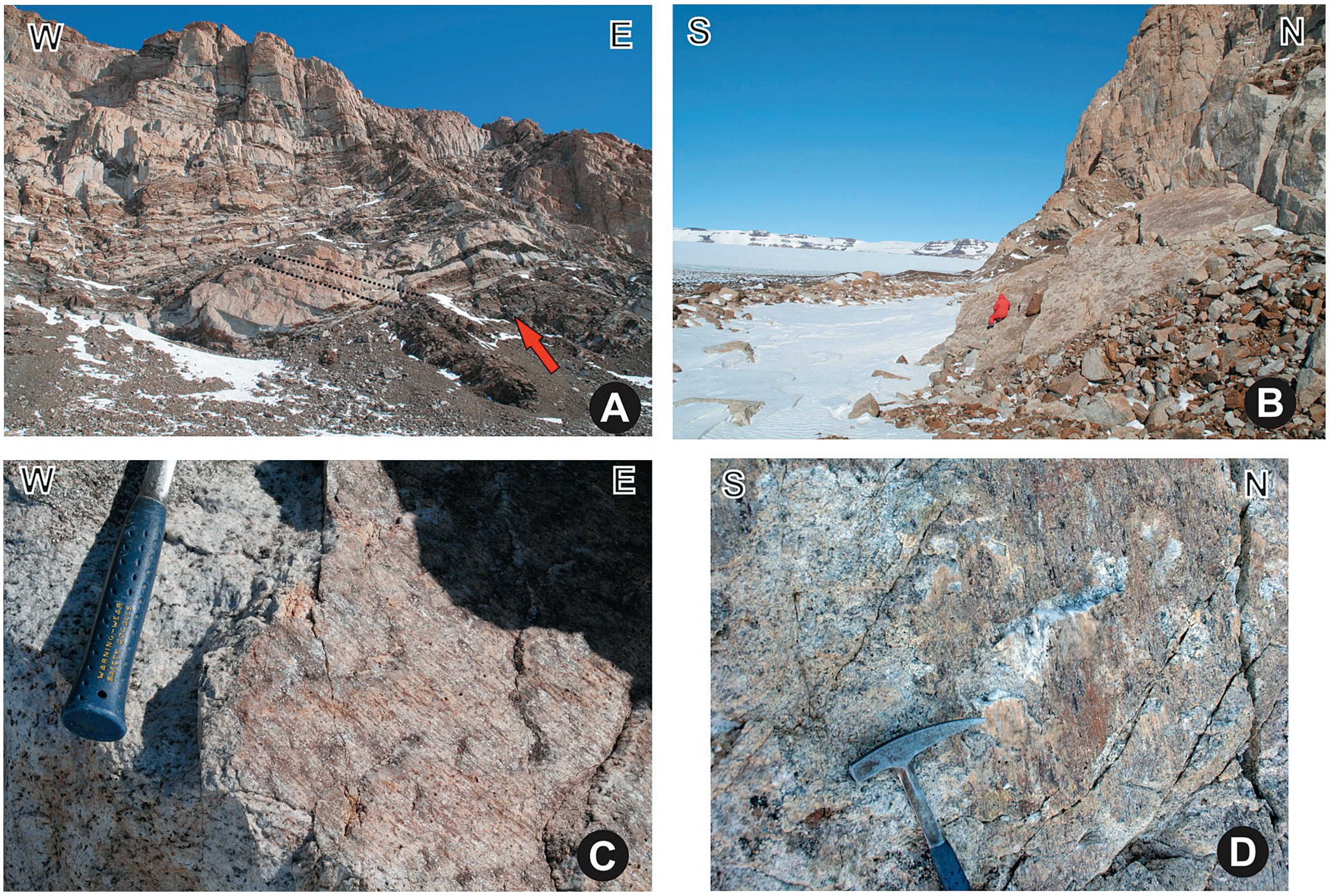

Fig. 4: (A) & (B) = Late Ross-orogenic brittle reverse faults with W to WSW directed shear senses overprint the ductile fabrics. Note the aplitic dyke (red arrow) intruding the brittle fault planes. (C) & (D) = The brittle fault planes are coated with quartz fibers and newly grown white mica. Sense of shear is top-to-W or -WSW.

Abb. 4 (A) & (B): Spät-ross-orogene spröde Aufschiebungen in Richtung W bis WSW, welche die duktilen Strukturen überprägen. Man beachte den aplitischen Gang (roter Pfeil), der die sprödtektonischen Störungsflächen benutzt. (C) & (D) = Die spröden Störungsflächen sind mit Quarzfaserkristallisaten und neu gesprossten Helglimmern belegt. Der Schersinn ist Top-nach-W bis -WSW.

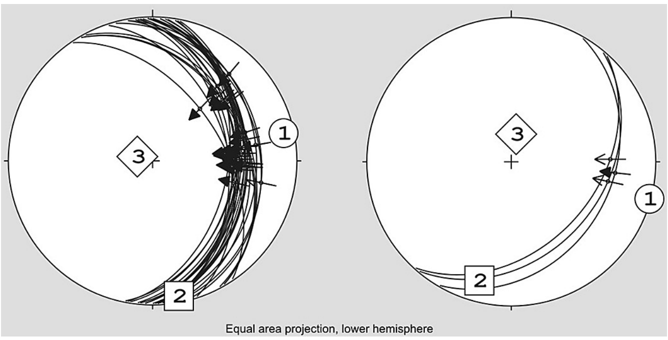

Fig. 5: Stereographic projections of the brittle fault planes within the northern (left) and the southern (right) flank of Lichen Hills (Fig. 4). The numbers 1, 2, and 3 correspond to the main principle stress axes σ1, σ2, and σ3, respectively.

Abb. 5: (E) Stereographische Projektionen der Sprödflächen von der Nordseite (links) und der Südseite (rechts) der Lichen Hills (Fig. 4). Die Zahlen 1, 2 und 3 entsprechen der Orientierung der Hauptspannungsachsen σ1, σ2, and σ3.

wana active margin. This is underlined by the observation that fault planes are oriented parallel to aplitic dykes, which indicates that the faults accommodated the emplacement of the dykes. So far, we have not found any signs of similar faults in the overlying Beacon and Ferrar units, where brittle fault planes are steeply inclined and show only steep or subhorizontal striations indicative of normal and strike-slip faulting.

A reconnaissance flight along the western margin of the upper Rennick Glacier verified comparable ductile deformation structures also in the neighbouring nunataks (up to Section Peak) further to the north and south of the visited outcrops at Lichen Hills. This supports the Lichen Hills Shear Zone being part of a regionally contiguous structure of significant importance within the Ross Orogen.

Possible Jurassic tectonics and volcanotectonics

As outlined before, the Ross-aged basement is covered by sedimentary and volcanic rocks of the Beacon and Ferrar formations, respectively. Nicely visible on the southern part of the Lichen Hills, the Ferrar volcanics can be separated by their general appearance into a lower, rather peculiar-looking, dark grey-coloured flow-like unit and an upper doleritic unit with its typical columnar jointing (Fig. 6A). Both units are separated by a layer of Beacon sandstones. Another lower unit of

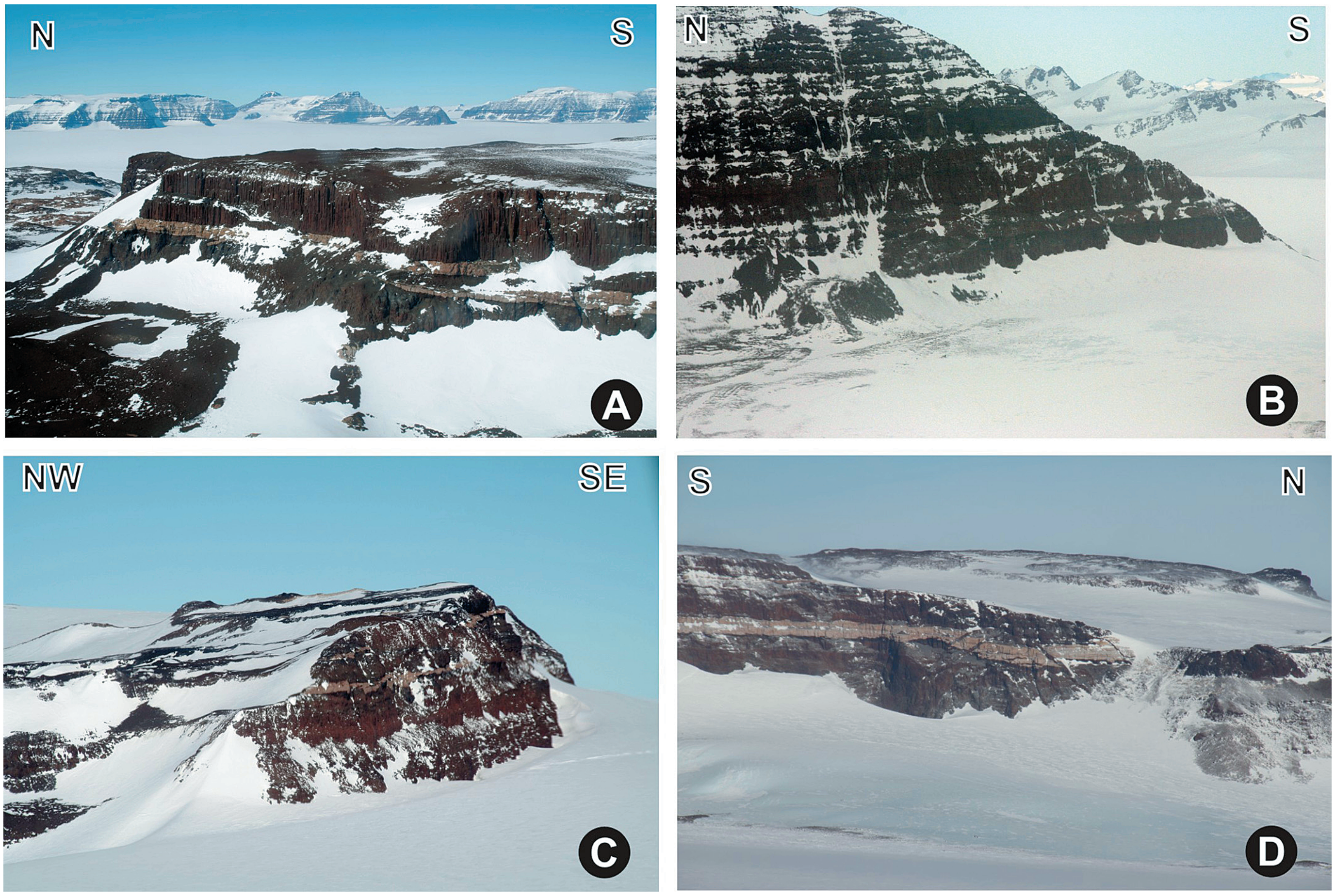

Fig. 6: Examples for possible Jurassic volcanotectonics. (A) = View across the southern Lichen Hills and the Rennick Glacier towards the Mesa Range. The Kukri erosion surface is covered by two layers of Beacon sandstone and two layers of Ferrar volcanics. The upper Beacon layer is disrupted and off-set by reverse and normal faults. The offsets and the Beacon layer are intruded by Ferrar dykes originating from the lower flow-like Ferrar unit and extending into the upper dolerite unit. (B) = Large-scale reverse fault within the western flank of the southernmost Gair Mesa (Mesa Range). (C) & (D) = Disrupted Beacon sandstones at Exposure Hill in the southern Mesa Range (C) and in the eastern face of Hülserberg Nunatak (D). Dykes originating from the lower intrude upwards into the upper Ferrar unit.

Abb. 6: Beispiele für eine mögliche jurassische Vulkanotektonik. (A) = Blick über die südlichen Lichen Hills und den Rennick Glacier auf die Mesa Range. Die Kukri-Erosionsfläche ist von zwei Paketen von Beacon-Sandsteinen und zwei Lagen bestehend aus Ferrar-Vulkaniten überlagert. Die obere Beacon-Lage ist durch Auf- und Abschiebungen zerrissen und versetzt. In die Versatzstellen und die Beacon-Lage sind Ferrar-Gänge aus der liegenden Ferrar-Einheit intrudiert und schlagen bis in den hangenden Ferrar-Dolerit durch. (B) = Großdimensionale Aufschiebungen in der Westflanke der südlichen Gair Mesa (Mesa Range). (C) & (D) = Zerrissene Beacon-Sedimentgesteine von Exposure Hills in der südlichen Mesa Range (C) und in der Ostwand von Hülserberg Nunatak (D). Vulkanische Gänge aus der liegenden Einheit schlagen bis in die hangende Ferrar-Einheit durch.

Beacon strata directly overlies the Kukri Peneplain, but is mostly covered by debris. The upper Beacon layer is repeatedly disrupted and off-set both by shallowly dipping reverse faults and steeply dipping normal faults. The reverse offsets and the Beacon strata are intruded by Ferrar dykes originating from the lower flow-like unit and extending into the upper dolerite unit, indicating that the lower one must be the younger of the two (cf. Schöner et al. 2007, Viereck-Götte et al. 2007).

Very similar Beacon-Ferrar field relations can be observed within the cliffs of Gair Mesa and Exposure Hill, both southern Mesa Range, located just opposite of Lichen Hills across the Rennick Glacier (Fig. 6 B-D). There, aerial views of the cliff show disruption of Beacon strata by a conjugate set of reverse faults. The faults and the Beacon sandstone layers are intruded by Ferrar dykes obviously originating from the lower Ferrar unit, again indicating this to be the younger of the two volcanic units.

In addition, rather broad aeromagnetic surveys flown over the Mesa Range during GANOVEX IV in 1984/85 (Bosum et al. 1989) suggest that the Ferrar volcanics there are oriented linearly and follow two main directions that are N–S and NW–SE. In addition, these linear geometry and several circular aeromagnetic highs along these lines could suggest the presence of eruption centres and possible feeder dykes that used a pre-existing (mainly Palaeozoic?) structural edifice that has been reactivated in Jurassic times as very likely extensional and/or transtensional faults coeval to Ferrar magmatic activity. However, a detailed structural analysis in combination with a high-resolution aerogeophysical survey is needed to prove or disprove this possibility.

Cenozoic tectonics

Steeply inclined brittle faults and joints are widely distributed in both basement and cover rocks (Fig. 7). The main sets of faults are approximately oriented N–S and NW–SE and, thus,

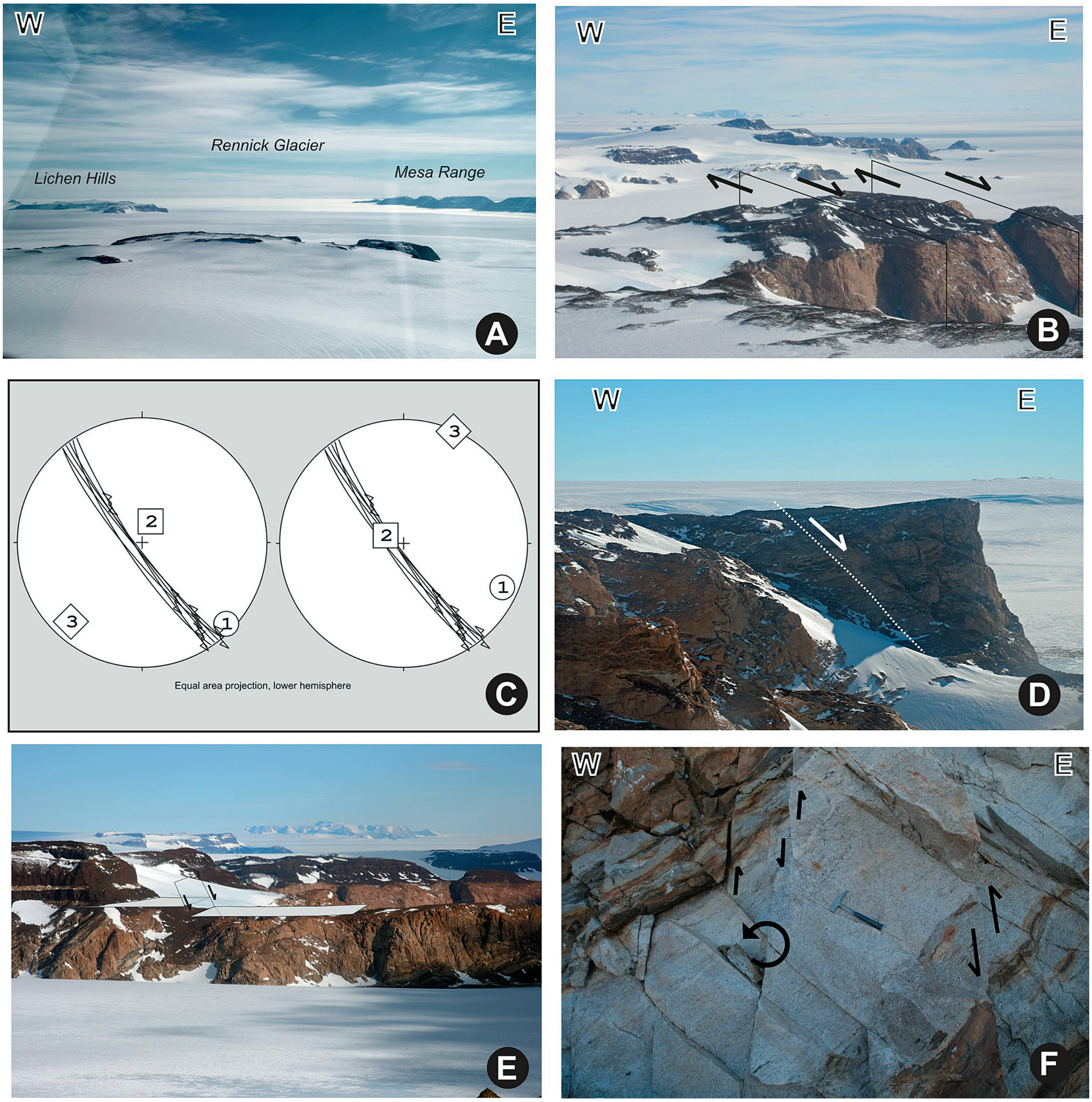

Fig. 7: Examples of post-Ross-orogenic brittle deformation. (A) = View from the S on the Rennick Glacier with Lichen Hills and Mesa Range on both sides. The Rennick Glacier follows the Cenozoic tectonic depression of the Rennick Graben and shows glacier-parallel dextral strike-slip faults on both margins. (B) = NW–SE striking right-lateral faults off-setting both basement and cover units at Section Peak N of Lichen Hills. (C) = Stereographic projections of right-lateral faults recorded at northern (left) and southern (right) Lichen Hills. The numbers 1, 2, and 3 correspond to the main principle stress axes $\sigma 1$, $\sigma 2$, and $\sigma 3$, respectively. (D) = Large-scale, Rennick Glacier-parallel normal fault offsetting structures of the Lichen Hills Shear Zone at southern Lichen Hills. (E) = View of northern Lichen Hills with the Lichen Hills Shear Zone: a large-scale Rennick Glacier-parallel normal fault off-sets the pre-Beacon/Ferrar Kukri Peneplain. (F) = Slightly rotated conjugate extensional faults in leucogranites and biotite schistose gneisses of the Lichen Hills Shear Zone. The brittle faults strike parallel to the Rennick Glacier.

Abb. 7: Beispiele für post-ross-orogene Spröddeformationsstrukturen. (A) = Blick von S auf den Rennick Glacier mit den Lichen Hills und der Mesa Range auf dessen beiden Seiten. Der Rennick Glacier folgt einer känozoischen tektonischen Depression – dem Rennick Graben – und zeigt in den Gesteinen auf beiden Rändern gletscherparallele Blattverschiebungszonen. (B) = NW–SE streichende Rechtsseitenverschiebungen, die sowohl das Grund- als auch das Deckgebirge des nördlich der Lichen Hills gelegenen Section Peak versetzen. (C) = Stereographische Projektionen (untere Halbkugel) rechtslateraler spröder Störungsflächen aus den nördlichen (links) und südlichen (rechts) Lichen Hills. Die Zahlen 1, 2 und 3 entsprechen der Orientierung der Hauptspannungsachsen $\sigma 1$, $\sigma 2$, and $\sigma 3$. (D) = Großdimensionale, parallel zum Rennick Glacier verlaufende Abschiebung in den südlichen Lichen Hills. Die Abschiebungen versetzen die duktilen Strukturen der Lichen Hills Scherzone um mehrere Meter. (E) = Blick auf die nördlichen Lichen Hills mit der Lichen Hills Scherzone: Eine großdimensionale, parallel zum Rennick Glacier verlaufende Abschiebung versetzt die prä-Beacon/Ferrar Kukri-Erosionsfläche. (F) = Leicht rotiertes konjugiertes Abschiebungssystem in Leukograniten und Biotit-Schiefergneisen der Lichen Hills Scherzone. Die Sprödstörungen streichen parallel zum Rand des Rennick Glacier.

follow the trend of Rennick and Campbell glaciers. Slickenlines on the faults are rather rare and indicate dextral displacement along the NW–SE trending planes. Faults striking N–S and parallel to the main Rennick trend rather show down-dip displacement. Offsets are in the order of several metres, which is particularly visible along the eastern, Rennick-ward face of Lichen Hills. Both the pre-Beacon Kukri palaeosurface and the post-Ferrar palaeosurface are tilted by some degrees towards the west and away from the Rennick Glacier, which fits the general normal faulting geometry. Since these faults affect basement, Beacon and Ferrar units, they must be post-Jurassic and in the regional context most likely Cenozoic in age.

DISCUSSION AND CONCLUSIONS

Structural data on ductile and associated late-stage brittle deformation in Ross-orogenic Granite Harbour leucogranites and schists of the Wilson Mobile Belt at Lichen Hills indicate the presence of a few 100 m thick reverse high-strain shear zone with top-to-ENE directed tectonic transport. Since (i) no ductile deformation was observed in Beacon and Ferrar rocks overlying the basement at Lichen Hills, (ii) ductile shearing has affected both metamorphic rocks and leucogranites of the Granite Harbour Intrusives, and (iii) thin, undeformed Granite Harbour aplitic dykes crosscut the shear zone, deformation and magmatism must be regarded roughly contemporaneous. Hence, based on the well-established age range of the late- to post-kinematic Granite Harbour Intrusive Suite (e.g., Goodge 2002 cum lit.), a late-Ross orogenic age can be confidently assumed for the time of shearing. An attribution to a possible mid-Palaeozoic orogenic event suggested by some authors for the areas further east (e.g., Capponi et al. 2002) can thus be ruled out.

The ductile structures of Lichen Hills described in this paper are comparable in age, kinematics, and deformation with prominent intra-Wilson Terrane high-strain basement thrusts located along strike further to the north and the south. These reverse shear zones are referred to be a part of the Wilson Thrust system, the type locality of which is located in the Wilson Hills along the Pacific coast (Flöttmann & Kleinschmidt 1991, 1993). In addition, these authors observed also an opposite directed high-strain thrust system in the Exiles nunataks, i.e. the Exiles Thrust system with its two branches Exiles and Lazarev thrusts. Kleinschmidt (1992) and Läufer & Rossetti (2003) were able to trace the Wilson Thrust system from the Pacific coast southwards into the areas of Renirie Rocks/Morozumi Range and Outback Nunataks, respectively. Similar high-strain reverse shear zones were observed along the western margin of the Campbell Glacier, located to the S of Lichen Hills (Palmeri et al. 1989, Castelli et al. 1989, Musumeci & Pertusati 2000, Di Vincenzo et al. 2007, Rossetti et al. 2007), which can also be attributed to the Wilson Thrust system (discussion in Läufer & Rossetti 2003). Significant breaks in the aeromagnetic and isotopic signatures in the area of central Victoria Land, which can be aligned with the observed structures, are well in line with this interpretation (Rocchi et al. 1998, Ferraccioli & Bozzo 1999).

Based on our structural data recorded at Lichen Hills and since it can be compared and directly linked with the aforementioned high-strain shear zones observed further north in the Outback Nunataks (Läufer & Rossetti 2003) and the western Campbell Glacier (Palmeri et al. 1989, Castelli et al. 1989, Musumeci & Pertusati 2000, Di Vincenzo et al. 2007, Rossetti et al. 2007), we suggest that the Lichen Hills Shear Zone represents the central segment of the Wilson Thrust system. ENE directed kinematics is well in line with W-directed subduction of the Palaeo-Pacific Ocean under the East Gondwana active margin represented by the Wilson Terrane in the Early Palaeozoic. Along this thrust system, the intra-Wilson Terrane arc and high-grade metamorphic basement represented by deep-seated Granite Harbour Intrusives and up-to granulite facies metamorphic rocks is displaced E-ward over lower-grade metamorphic rocks and shallow-level intrusives (Läufer & Rossetti 2003). According to the geodynamic model of Flöttmann & Kleinschmidt (1991) and Läufer et al. (2006a), the bi-vergent Wilson and Exiles thrust systems form the internal portion of a large-scale fold-and-thrust belt, along which the central high-grade Wilson Terrane is displaced over its eastern forearc and western backarc regions in late Ross-orogenic times in the Early Palaeozoic.

Reverse offsets locally visible in Beacon strata of southern Lichen Hills and the southern Mesa Range are interpreted to be related to volcanotectonic events during the intrusion of the Ferrar volcanics, because the faults are filled with Ferrar dykes originating in the lower of the two volcanic units covering the basement rocks. Evidence of Jurassic tectonics was not found during our survey, but the N–S and NW–SE oriented linear alignment of Ferrar volcanics and circular magnetic highs detected during the GANOVEX IV (1984/85) aerogeophysical survey (Bosum et al. 1989) suggests the presence of extensional and/or transtensional faults acting as passage ways for the Ferrar rocks. A high-resolution aeromagnetic survey along with structural field work, however, is needed to verify this hypothesis.

NW-SE striking subvertical brittle faults with slickenlines indicating dextral movement and N-S striking (i.e. parallel to the Rennick Glacier) large-scale normal faults, which off-set basement structures and cover rocks, are interpreted to be Cenozoic in age. They fit well into the general structural setting described for present northern Victoria Land and the Oates Coast following Gondwana break-up and are related to the formation of the Cenozoic Rennick Graben within the frame of West Antarctic rifting and the formation of a mainly Neogene NW–SE oriented right-lateral strike-slip belt (e.g., Rossetti et al. 2003, 2006, Kleinschmidt & Läufer 2006, Storti et al. 2006, Damaske et al. 2007). The large-scale normal faults that can be observed in the eastern (i.e. Rennick-wards) flank of Lichen Hills indicate block tilting in the order of several degrees towards the polar plateau. They also control the formation of half grabens with Lichen Hills and the Mesa Range representing the western and eastern uplifted horsts, respectively.

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