Polarforschung 84 (1), 49–58, 2014

Sedimentological Field Investigations on the Takrouna Formation (Permian, Beacon Supergroup) in Northern Victoria Land, Antarctica

by Robert Schöner[1] and Nadine John[1]

Abstract: The deposits of the Takrouna Formation (Permian) were target of sedimentological field work during the 10th "German North Victoria Land Expedition" (GANOVEX X, 2009/2010). Four complete and several small sections were logged within six different mountain ranges in the northern part of Victoria Land. Lithofacies types of the studied sedimentary succession mainly comprise fluvial conglomerates and coarse- to fine-grained sandstones, and enable a subdivision in preliminary units. The lithofacies characteristics also allow tracing the transition of more proximal and distal parts of the fluvial system of the Takrouna Formation. Coarse-grained successions in the eastern part of the study area were probably deposited close to the basin margin. Further west sedimentary successions are overall finer and show a great variety of facies and fluvial architecture. They most likely represent locations close to the basin axis. At the basin margin the river system remained highly energetic in contrast to a more variable depositional environment towards the basin axis.

Zusammenfassung: Die Ablagerungen der Takrouna Formation (Perm) waren Ziel sedimentologischer Untersuchungen während der 10. „Deutschen Nord-Viktorialand-Expedition" (GANOVEX X 2009/2010). In insgesamt sechs Gebirgszügen wurden vier vollständige und mehrere kurze Profile sedimentologisch aufgenommen. Die Lithofaziestypen umfassen größtenteils fluviatile Konglomerate und Grob- bis Feinsandsteine. Die Geländebefunde erlauben eine vorläufige Unterteilung der sedimentären Abfolge in mehrere Einheiten und eine Unterscheidung zwischen proximalen und mehr distalen Bereichen des ehemaligen Flusssystems. Durchgehend grobkörnige Abfolgen im östlichen Teil des Untersuchungsgebietes wurden vermutlich nahe des Beckenrandes abgelagert. Die weiter westlich gelegenen Profile sind insgesamt feinkörniger und hinsichtlich Fazies und fluviatiler Architektur variabler. Sie wurden distaler abgelagert, wahrscheinlich im Bereich der Beckenachse.

INTRODUCTION

During the 10th German North Victoria Land Expedition (GANOVEX X) in the Austral summer 2009/2010, the Permian Takrouna Formation and locally the underlying deposits of supposed glacial origin were target of sedimentological fieldwork. Sedimentary rocks of the Takrouna Formation are exposed in several mountain ranges in the northern part of Victoria Land (Figs. 1 & 2). The current knowledge on the Takrouna Formation is based on field campaigns that were carried out in the 1970s and 1980s by Dow & Neall (1974), Walker (1983), Collinson & Kemp (1983), and Collinson et al. (1986). Although previous investigations indicate the Fluvial nature of the Takrouna Formation, the available data does not allow drawing a consistent picture of the depositional evolution of the roughly north-south oriented sedimentary basin. Sections from different parts of the basin could not be correlated so far. The major target of this field campaign was investigating the sedimentary inventory of the Takrouna Formation in detail throughout the exposed stratigraphic range. The localities selected are lined along two east-west and north-south trending axes in order to work out lateral changes across and along the basin. Detailed logging of vertical sections in combination with the study of large two-dimensional exposures (cliff faces) will help to better understand the sedimentological and stratigraphic evolution of the Permian succession in northern Victoria Land. The results will also allow comparing this basin with other contemporaneous basins in the Transantarctic Mountains.

This report provides a brief overview over the fieldwork on the Takrouna Formation carried out during GANOVEX X. Coordinates and elevations given in this report were recorded by GPS (WGS 84). Samples taken systematically will serve for further petrographical and provenance analytical studies as well as for biostratigraphic investigations.

GEOLOGICAL SETTING AND STRATIGRAPHY

Sedimentary rocks of the Beacon Supergroup of the Transantarctic Mountains rest unconformably on pre-Devonian basement composed of metamorphic and igneous rocks. The Beacon Supergroup was deposited in Devonian to Early Jurassic times in a sedimentary basin at the Panthalassan margin of Gondwana (Barrett 1991). It can be subdivided into the Devonian Taylor Group, and the Upper Carboniferous to Lower Jurassic Victoria Group. In northern Victoria Land, the Victoria Group consists of an unnamed basal diamictite unit and the overlying Takrouna Formation (Upper Carboniferous (?) to Permian; Dow & Neall 1974), the Triassic to Lower Jurassic Section Peak Formation (Collinson et al. 1986, Schöner et al. 2011), and the Lower Jurassic Shafer Peak Formation (Schöner et al. 2007). Volcaniclastic deposits of local phreatomagmatic eruptions are crosscutting the Section Peak and the Shafer Peak formations, and are also intercalated within the Lower Jurassic part of the sedimentary succession (Viereck-Götte et al. 2007, Schöner et al. 2007).

During the Late Carboniferous and earliest Permian northern Victoria Land was located close to the South Pole and affected by continental glaciation. After the retreat of the glaciers and the beginning of glacially controlled sedimentation (Laird & Bradshaw 1981, Skinner 1981), a fluvial system was established probably during Early Permian times. Permian sedimentary rocks of the Central Transantarctic Mountains and of Victoria Land were deposited in two different basins,

[1] Friedrich-Schiller-Universität Jena, Institut für Geowissenschaften, Burgweg 11, D-07749 Jena, Germany, <robert.schoener@gmx.de>, <nadine.jo@gmx.de>

Manuscript received 03 June 2014; accepted in revised form 06 November 2014.

which were separated by the Ross High (Collinson et al. 1994). Paleocurrent data indicate overall sediment transport-directions towards the south in the Central Transantarctic Mountains, and towards the north in Victoria Land. The Ross High apparently became inactive during the Triassic, when a north-oriented drainage system established throughout the Transantarctic Basin (Barrett 1991, Collinson et al. 1994). However, there is no continuous record of Permian to Triassic sedimentation in northern Victoria Land. Outcrops of Permian deposits occur only in the northern part, whereas Triassic deposits have only been described from the southern part of northern Victoria Land. The emplacement of large volumes of mafic magma during the late Early Jurassic (Ferrar Group) led to the intrusion of mafic dolerite sills into the Beacon Super-group, and to the deposition of a thick sequence of lava flows.

LOGISTICAL CONSTRAINTS AND SCHEDULE

To carry out sedimentological investigations on the approximately 300 m thick Takrouna Formation, five small satellite camps were planned at key localities. Four of these camps could be realized in Boggs Valley (Helliwell Hills), at De-Goes Cliff (Morozumi Range), in the northern Alamein Range, and close to Neall Massif (Figs. 1 & 2). These areas were investigated within five to eight days depending on weather conditions and helicopter availability. The field party consisted of Nadine John, Robert Schöner and Mike Aitkinson (field guide) and was equipped with one Polar tent (kitchen tent) and three lightweight geodetic tents (Fig. 5). People and equipment were transferred from camp to camp by two helicopter loads. The camp at Boggs Valley had to be carried to a more sheltered location after the first night due to strong catabatic winds. Walking distances from the camps to the outcrops varied between 1 km and 5 km. In total, 27 days were spent in the camps between January 03 and 29 2010. Helicopter supported reconnaissance surveys to key outcrops that could not be reached from the camps were originally planned at the beginning and end of the field campaign, and in combination with each camp move. However, apart from one short stop on a plateau above Boggs Valley (section 1BT, Tab. 1), all reconnaissance flights were cancelled owing to poor weather conditions or limited helicopter availability. After the last camp was closed down these reconnaissance flights could be partly completed. In total, helicopter reconnaissance was limited to one full day and two half days, which were used for brief visits of outcrops in the Lanterman Range, the Morozumi Range, the southern Freyberg Mountains, the Retreat Hills, and additionally for two outcrops of the Triassic Section Peak Formation at Vulcan Hills and Timber Peak (Figs. 1 & 2, Tab. 1). Sedimentological fieldwork was carried out for 18.5 days in total, which is equivalent to 64 % of the time spent in the working area, and about 30 % of the time spent on the expedition.

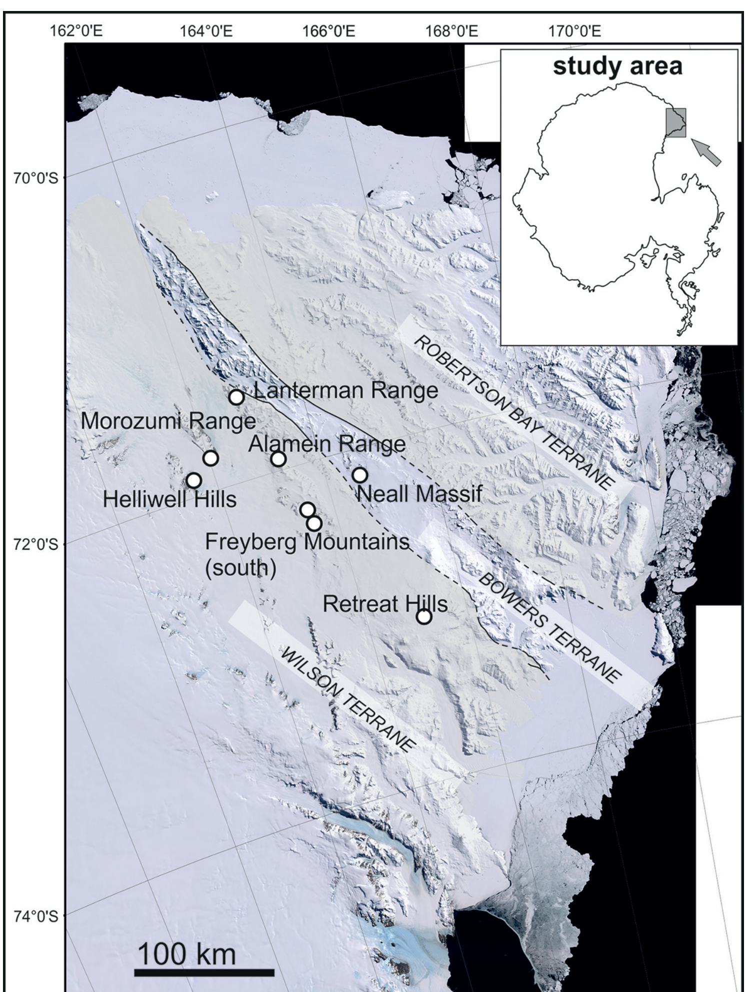

Fig. 1: Map of northern Victoria Land indicating the studied Permian sections in the Rennick Glacier region (compiled using satellite images from USGS-LIMA, 2009).

Abb. 1: Karte des nördlichen Victoria Land mit den untersuchten permischen Aufschlüssen im Bereich des Rennick Glacier (zusammengestellt auf Basis von USGS-LIMA, 2009).

RESULTS OF FIELD INVESTIGATIONS

Helliwell Hills

Exposures of the Takrouna Formation in the Helliwell Hills occur in Boggs Valley, southeast of Mt. Remington and south of Mt. Bresnahan. Since reconnaissance flights previous to the field period could not be carried out, the locality Boggs Valley, exposing the largest known outcrops with a thickness of 225 m (COLLINSON et al. 1994), was chosen for the first camp.

The outcrops at the nearly NE-SW trending valley were examined between January 03 and 08 2010 (Fig. 8). A continuous 3 km section was studied at the northern side of the valley and a cumulative thickness of about 180-190 m was measured. The sedimentary rocks are separated into several units by mafic dolerite sills of the Ferrar Group, which are thicker than the exposed sedimentary units. These sills also form the top of the peaks surrounding Boggs Valley. A 120 m section of the lower part of the sedimentary succession was studied in detail at the SE-facing cliff near the eastern end of the valley (section BV, Fig. 2, Tab. 1). Parts of the upper succession were investigated between two thick sills about 3 km further WSW, above a small plateau directly north of the valley (section BT). Additionally, sedimentological features and sedimentary architecture were studied on a cliff in the central part of the valley.

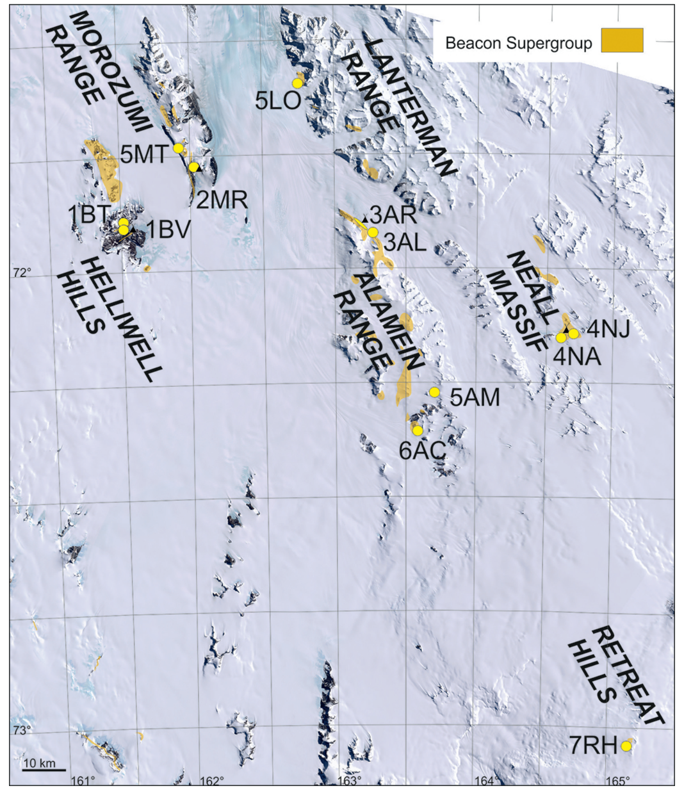

Fig. 2: Map of the working area showing outcrops of the Takrouna Formation in northern Victoria Land, including field camps and the studied localities: AC = Monte Cassino, AL = unnamed peak 10 km northwest of Takrouna Bluff, AM = Moawhango Névé, AR = Northern Alamein Range cliff, BT = Plateau directly north of Boggs Valley, BV = Boggs Valley, LO = Spur north of the Orr glacier, MR = DeGoes Cliff, MT = Plateau northwest of DeGoes Cliff, NA = West end of Neall Massif ridge, NJ = Central part of Neall Massif ridge, NM = East end of Neall Massif ridge, RH = southern peak of Retreat Hills. Map compiled using satellite images from USGS-LIMA (2009) and the geological map of GANOVEX-Team (1987).

Abb. 2: Karte des Arbeitsgebietes mit Aufschlüssen der Takrouna Formation im nördlichen Victoria Land einschließlich der Feldlager und der untersuchten Lokalitäten: AC = Monte Cassino, AL = unbenannter Berg 10 km nordwestlich des Takrouna Bluff, AM = Moawhango Névé, AR = Nördliches Kliff der Alamein Range, BT = Plateau unmittelbar nördlich von Boggs Valley, BV = Boggs Valley, LO = Felsrücken nördlich des Orr Glacier, MR = DeGoes Cliff, MT = Plateau nordwestlich von DeGoes Cliff, NA = westliches Ende des Felsrückens im Neall Massif, NJ = zentraler Teil des Felsrückens im Neall Massif, NM = östliches Ende des Felsrückens im Neall Massif, RH = südlicher Felsgipfel der Retreat Hills. Kartengrundlage zusammengestellt auf Basis von USGS-LIMA (2009) und GANOVEX-Team (1987).

Boggs Valley (section BV)

The basement is exposed along the valley floor and consists predominantly of meta-sedimentary rocks belonging to the Rennick Schists, which comprise a variety of quartzites and finer-grained meta-sediments. Acidic igneous intrusive bodies contain partly high amounts of tourmaline and increase in abundance towards the western end of the valley (Fig. 3). The basal 15 m to 20 m of the sedimentary succession above the basement are covered by scree. The exposed succession starts with beige to medium-grey fine-grained clastic deposits followed by several sandy fining-up units. A mafic dolerite sill intrusion is exposed about 60 m above the base of the valley floor. The top of the sill and the overlying deposits are covered beneath scree. Further up, the exposed sequence continues with predominantly medium-grained sandstone showing ripple cross-lamination and less abundant trough crossbedding. At the top of this unit, paleo-soil relics such as root traces and iron-bearing concretions were observed. The overlying part of the section (71°54.137' S, 161°32.350' E, 840 m) is characterized by a laterally continuous light-beige coloured, pebble- and cobble-dominated conglomeratic layer that introduces a succession of fining-up units typically comprising coal-bearing fine-grained deposits at the top. Paleocurrent directions were measured throughout the sections using mainly trough cross-strata, or trough axis where exposed, as well as some planar cross-stratified beds. Measurements at section BV yield mean paleocurrent directions towards the NW.

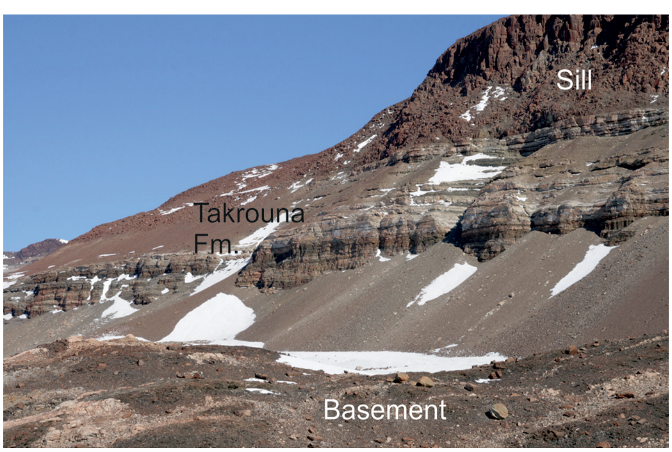

Fig. 3: Outcrop of the Takrouna Formation at the NW side of Boggs Valley in between basement and dolerite sill (Ferrar Group). The basement consists of Rennick Schists (dark) and acidic intrusives (bright). The sedimentary section was measured about 1 km further to the NE (section BV).

Abb. 3: Aufschluss der Takrouna Formation an der NW-Flanke von Boggs Valley zwischen Grundgebirge und einem Lagergang der Ferrar Group. Das Basement besteht hier aus Rennick Schists (dunkel) and felsischen Intrusiva (hell). Das Profil wurde ca. 1 km weiter im NE aufgenommen (Profil BV).

Area	Locality	Section	Longitude S	Latitude E	Elevation (m) a.s.l.	Base	Top	working from	Formation
Helliwell Hills	Boggs Valley	1BV	71°54.0'	161°32.7'	760	Rennick Schists	Ferrar sill	camp	Takrouna Fm.
	Boggs Valley top	1BT	71°74.8'	161°26.0'	1360	Rennick Schists	Ferrar sill	helicopter	Takrouna Fm.
Moruzumi Range	De Goes Cliff	2MR	71°47.2'	161°59,0'	810	Morozumi Phyllites	Ferrar sill	camp	glacial deposits, Takrouna Fm.
	Morozumi Range top	5MT	71°41.6'	161°49.9'	1360	Ferrar sill	not exposed	helicopter	Takrouna Fm.
Freyberg Mountains	Alamein Range	3AL	71°55.0'	163°11.9'	1320	Granite Harbour Intrusives	Ferrar sill	camp	glacial deposits Takrouna Fm.
	Alamein Range cliff	3AR	71°53.6'	163°07.6'	1000	not exposed	Ferrar sill	camp	Takrouna Fm.
	Moawhango Névé	5AM	72°15.7'	163°30.1'	1810	not exposed	not exposed	helicopter	Takrouna Fm.
	Monte Cassino	6AC	72°21.4'	163°34.0'	1570	not exposed	Ferrar sill	helicopter	Takrouna Fm.
Neall Massif	Neall Massif east	4NM	72°08.8'	164°43.6'	2070	Molar Formation metasediments	not exposed	camp	glacial deposits
	Neal Massif camp	4NJ	72°08.6'	164°39.6'	1990	Ferrar sill	Ferrar sill	camp	Takrouna Fm.
	Neal Massif west	4NA	72°08.5'	164°31.2'	1790	Ferrar sill	not exposed	camp	glacial deposits Takrouna Fm.
Lanterman Range	S' spur N' Orr Glacier	5LO	71°35.2'	162°45.7'	530	Lanterman Metamorphics	not exposed	helicopter	glacial deposits Takrouna Fm.
Retreat Hills	Retreat Hills	7RH	73°02.9'	165°11.0'	3020	not exposed	not exposed	helicopter	Takrouna Fm.
Vulcan Hills	Vilcan Hills	7VH	73°40.1'	163°40.0'	2760	Granite Harbour	Ferrar sill	helicopter	Section Peak Fm.
Timber Peak	Timber Peak	8TI	74°11'	162°31'	2840	Ferrar sill	Ferrar sill	helicopter	Section Peak Fm.

Tab. 1: Outcrops of Permian / Permo-Carboniferous deposits investigated during GANOVEX X (2009/2010). Coordinates and elevations were taken by GPS (WGS 84).

Tab. 1: Aufschlüsse permischer / permokarboner Ablagerungen, die während GANOVEX X (2009/2010) untersucht wurden. Koordinaten und Höhen wurden mittels GPS (WGS 84) aufgezeichnet.

Plateau directly north of the valley (section BT)

A short helicopter stop was used to note the most important features and to sample the upper sedimentary rocks above a major dolerite sill (section BT). During this brief stop an approximately 20-25 m thick, cross-bedded sandstone unit was noticed, containing horizons with intense bioturbation of predominantly *Skolithos*-like burrows.

Morozumi Range

The Takrouna Formation is exposed in the western part of the Morozumi Range in the area between Jupiter Amphitheatre and Paine Ridge. The most complete section with a thickness of 280 m has been briefly described from DeGoes Cliff in the southern Morozumi Range by Walker (1983).

We re-investigated this section from a field camp located west of the cliff during January 08 and 16, 2010 (section MR; Figs. 2 & 8, Tab. 1). The best exposures, found at the steep, east-facing, about 6 km long DeGoes Cliff, are located north of a prominent ice cliff (Fig. 4). A second outcrop on a plateau on top of a thick mafic dolerite sill was visited during a reconnaissance survey about 10 km further NNW (section MT).

DeGoes Cliff (section MR)

At the base of the sedimentary section, a heterogeneous, poorly sorted conglomerate forms a thin, discontinuous unit above the basement. It contains basement clasts up to 30 cm in size and fill up to 6 m of local paleo-relief. Fluvial conglomerate and sandstone of the Takrouna Formation were deposited either above this unit or, locally, directly on top of basement rocks. The erosive base of the conglomerate can be traced over a minimum distance of 1 km along the cliff and shows local scours of up to 1 m depth. The lowermost deposits of the Takrouna Formation at DeGoes Cliff are approximately 45 m of cross-bedded fine-grained conglomerate and coarse-grained sandstone, which are whitish to light-grey in colour. They are overlain by an about 100 m thick unit consisting of fine-grained conglomerate to coarse-grained sandstone layers with erosive base, separated by finer-grained, grey to black deposits dominated by carbonaceous sand- and siltstone. These deposits typically show fining-upward trends and frequently contain coal seams at the top. This unit is overlain by another 20 m of whitish, crossbedded conglomerate and sandstone, forming a prominent cliff in the middle part of the section (Fig. 3). The following 25 m show several well-developed fining-upward units from coarse-grained sand to fine-grained, carbonaceous sand and silt. The overlying deposits are dominated by light- to dark-grey and greenish-grey, medium- and fine-grained, carbonaceous and non-carbonaceous sandstone, which form a package of about 55 m thickness. Most abundant sedimentary textures are ripple cross-lamination and trough crossbedding. The uppermost, about 30 m thick unit is again dominated by whitish coarse-grained sandstone and fine-grained conglomerate. The top of the cliff is formed by a dolerite sill of the Jurassic Ferrar Group, which can be traced laterally over many kilometres along the Morozumi Range. Paleocurrent measurement carried out on sandstones of the Morozumi Range show an azimuthal range from 140° to 310° (mean flow towards NW).

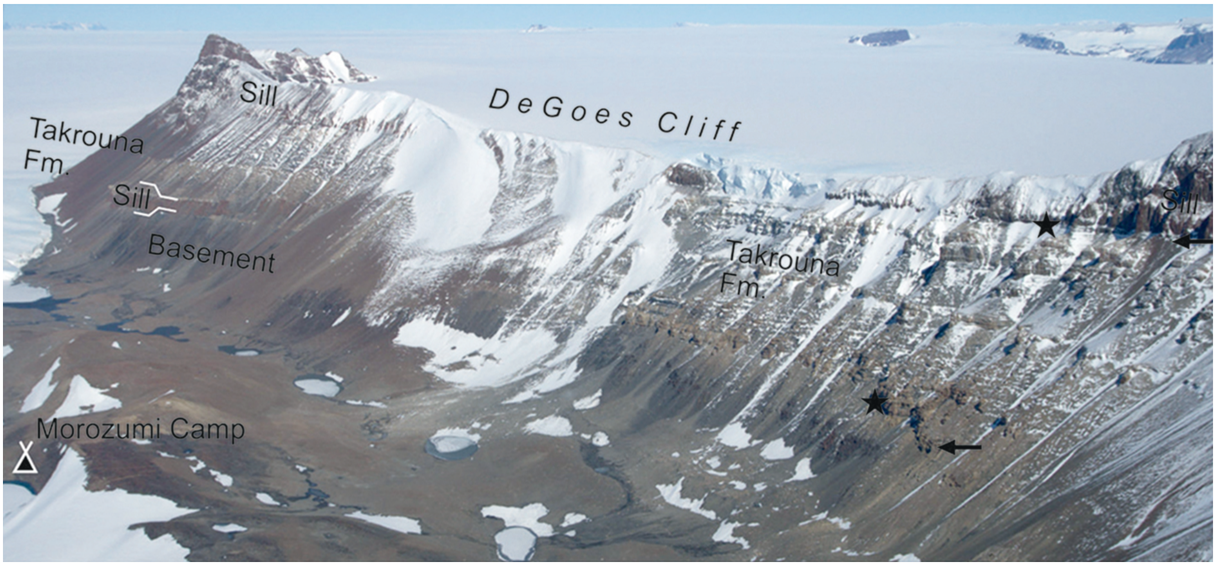

Fig. 4: DeGoes Cliff in the southern part of the Morozumi Range facing towards ENE. The measured section of the Takrouna Formation is indicated by the lower and upper asterix (section MR).

Abb. 4: In der nach ENE gewandten Steilwand (DeGoes Cliff) im Südteil der Morozumi Range wurde ein vollständiges Profil im aufgenommen (Profil MR, zwischen den beiden mit Stern markierten Punkten).

Plateau on the northwest side of DeGoes Cliff (section MT)

The approximately 55 m section MT (Fig. 2) above the sill consist of predominantly medium-grained sandstone showing cross-bedding and ripple cross-lamination, and locally comprise coalified plant axes. Some layers show white spots on weathering surfaces and tube-like vertical traces that are interpreted as bioturbation. The stratigraphic relationship to the section measured at DeGoes Cliff remains yet uncertain, because the sill is not strictly conformable.

Northern Freyberg Mountains

The Takrouna Formation is exposed in the eastern part of the Alamein Range, in particular along the western side of the Canham Glacier, and at the northern flank of an unnamed peak in the western Alamein Range (COLLINSON et al. 1986). The type section of the Takrouna Formation described by DOW & NEALL (1974) is located 4 km NW of the actual Takrouna Bluff below a thick mafic dolerite sill (COLLINSON et al. 1986), comprising a 60 m thick succession of *Glossopteris*-bearing sandstone. A 280 m thick sequence has been mentioned north of Takrouna Bluff, but has not been investigated before.

The Alamein Range has been a key locality during this field campaign (Fig. 2). Fieldwork in this area could be carried out from January 16 until 21, 2010. We studied the sedimentary sequence on an E-facing slope about 10 km NW of Takrouna Bluff (section AL, Figs. 3 & 8, Tab. 1) and measured a cumulative thickness of approximately 300 m. The camp was located on the west side of Canham Glacier at a prominent NE-facing cliff, which represents the second outcrop investigated in detail (section AR).

Alamein Range – unnamed peak 10 km NW of Takrouna Bluff (section AL)

The basement at section AL consists of Granite Harbour Intrusives, which are unconformably overlain by a poorly exposed alternation of grey to greenish-grey silt- and fine-grained sandstone, and carbonate containing fine-grained clastic detritus. Some carbonate units show fibrous calcites and bioturbation; some nodular as well as some brecciated horizons have been observed. The overlying, approximately 10 to 15 m thick, poorly sorted conglomerate unit contains a range of metamorphic and igneous basement clasts. The following succession is dominated by coarse-grained and pebbly, cross-bedded sandstone, intercalated with medium-grained sandstone, carbonaceous fine-grained sand- and siltstone, and fine-grained conglomerate. Grain size trends and sedimentary textures allow a subdivision of the succession into several distinct packages. The top of the section is formed by a thick dolerite sill, which can be traced to the northernmost tip of the Alamein Range.

Northern Alamein Range cliff (section AR)

The upper part of the section has been investigated along the approximately 3 km-long NW-SE trending cliff close to the camp, which provides excellent 2-3D exposures (section AR, Fig. 5). The lowermost part at the southern end of the cliff (71°53.6 S, 163°07.6 E, 998 m) exposes a fining-up sequence at the glacier level, followed by a pebbly, coarse-grained sandstone unit of a more tabular and laterally extensive nature. The section continues with a 90 m thick succession of predominantly medium- to coarse-grained sandstone mainly consisting of large-scale channel bodies. The top of the sedimentary section, accessible at the northern end of the cliff, is distinct light-grey to white in colour and comprises evidence of bioturbation, paleosoil relics and *Skolithos*-like burrows. Measured paleocurrent data indicate a relatively constant direction towards the NW.

Fig. 5: Field camp at the NE-facing cliff (Takrouna Formation, section AR) in the northern Alamein Range (Freyberg Mountains). The slope visible in the background is part of the outcrop exposing the base of the section and the underlying igneous basement (section AL).

Abb. 5: Feldlager an der nach NE gewandten Steilwand (Takrouna Formation, Profil AR) im Nordteil der Alamein Range (Freyberg Mountains). Die im Hintergrund sichtbare Flanke gehört zu dem Aufschluss an dem die Basis der sedimentären Abfolge und die unterlagernden Magmatite aufgeschlossen sind (Profil AL).

Southern Freyberg Mountains

Outcrops in the southern part of the Freyberg Mountains were described at several localities by previous workers at Smiths Bench, Mt. Camelot, Mt. Baldwin, Mawhango Névé and Monte Cassino (Dow & Neall 1974, Walker 1983, Collinson & Kemp 1983, Collinson et al. 1986).

The planned camp at Monte Cassino had to be canceled due to logistical constraints and poor weather conditions. However, a complete section at the east facing slope south of Monte Cassino and parts of the section and at a south-east facing cliff at the southern tip of Mawhango Névé were investigated during two helicopter reconnaissance surveys (Tab. 1, Figs. 2 & 8).

Monte Cassino (section AC)

The lower part of the exposed section is dominated by alternations of cross-bedded sandstone and carbonaceous sand- and siltstone showing overall fining-upward trends. The upper part consists mainly of fining-up units beginning with pebbly, coarse-grained erosive sandstone bodies grading into ripple-laminated, medium-grained sandstone. Some concave-up surfaces with lateral extents at meter scale are filled by medium- to fine-grained sandstone and comprise coalified plant axes. The top of the sedimentary succession, underneath a mafic dolerite sill of the Ferrar Group, consists of a 10 m thick unit composed of several fine-grained conglomeratic to coarse-grained sandstone bodies with up to 80 cm thick cross-bedding sets.

Moawhango Névé (section AM)

The succession at this location is composed of predominantly medium- to coarse-grained, trough cross-bedded, ripple-laminated as well as planar cross-bedded sandstone, typically forming thin, lateral extensive bodies. Remains of plant axes on the bedding surfaces and patchy distributed, roundish weathering cavities with an average size of 1 cm occur within all units. The small cavities probably represent traces of bioturbation. Paleocurrent directions at both sections AC and AM point mainly towards the WSW.

Neall Massif

Outcrops of the Takrouna Formation and underlying heterogeneous diamictite deposits occur at several ridges and peaks in the Neall Massif area, east of Black Glacier. We studied the outcrops along the unnamed east-west-trending ridge south of Neall Massif, some of which were already described by Collinson et al. (1986). Additional to the outcrops mapped in the northern part of Neall Massif and at the Jago Nunataks (GANOVEX-Team 1987), rewarding sections of sedimentary rocks were observed from the helicopter at the western margin of Neall Massif, but could not be studied on the ground.

The campsite (January 21 to 28) was located in a central position directly north of the unnamed ridge, thus all parts of the ridge were accessible by foot within less than 5 km (Figs. 2 & 8, Tab. 1). The approximately 8 km long ridge south of Neall Massif consists of low-grade meta-sedimentary basement rocks in the eastern part, and roughly W-dipping (10-15°) sedimentary rocks and intrusive Ferrar dolerites in the central and western part.

East end of the ridge (section NM)

The base of the sedimentary succession is exposed at a peak near the east end of the ridge (Fig. 2, Tab. 1). The basal deposits consist of unsorted to poorly sorted, partly matrix-supported conglomerate, sandy greenish-grey to dark-grey pelites and locally carbonate beds; the latter two lithologies are poorly exposed. The conglomerate form the small peak at the GPS-position 72°08.8’ S, 164°43.2’ E, 2050 m. It contains a variety of clast types including granite, granodiorite, felsic to intermediate volcanic rocks, quartzite, fine-grained greenish metamorphic rocks, fine-grained dark-grey to black clasts, schists, clastic sedimentary rocks, quartz and feldspar. The largest boulders observed in-situ measure about 30 cm in diameter, but rounded boulders up to a size of 1.2 m occurring in the debris may also be derived from this unit. The adjacent peak about 1 km to the west is mainly formed by whitish to light-grey sandstone, but could not be investigated in more detail.

Central part of the ridge (section NJ)

At the central part of the ridge, an about 35-40 m thick sandstone unit is exposed in between two dolerite sills (section NJ, Fig. 2, Tab. 1). The stratigraphic position of these sedimentary rocks is yet unclear (Fig. 6). The contact of sedimentary rocks to the underlying sill is sharp and the lowermost 10 cm are strongly cemented and very solid. The upper contact zone of at least 3 m thickness contains brownish rocks with relics of sedimentary textures and many irregular fissures. The sedimentary section is dominated by light-grey and brownish-grey

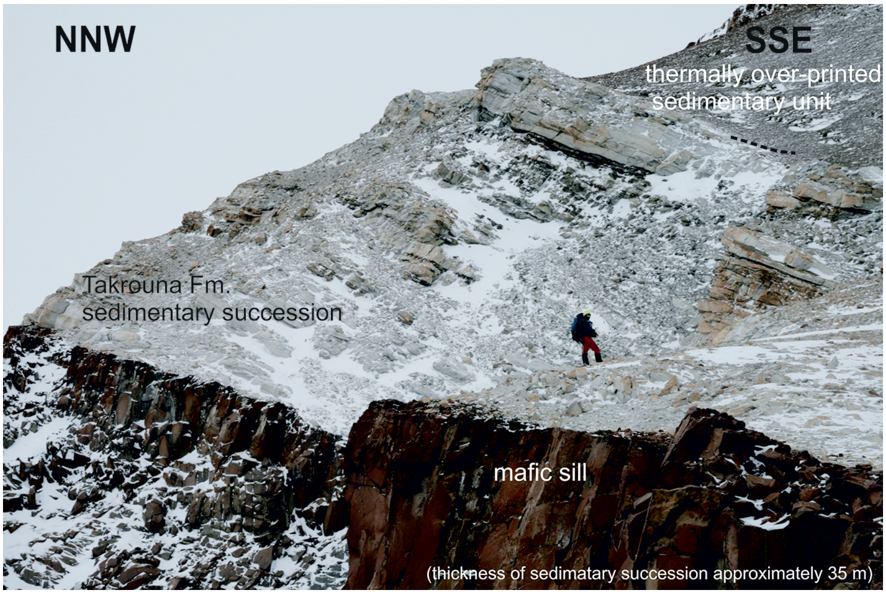

Fig. 6: Sedimentary succession (section NJ) about 500 m SE of the camp site at Neall Massif. The sedimentary rocks are enclosed by two dolerite sills of the Ferrar Group.

Abb. 6: Sedimentgesteine der Takrouna Formation (Profil NJ) etwa 500 m SE des Feldlagers im Neall Massif. Die Sedimentgesteine sind hier zwischen zwei Lagergängen der Ferrar Group aufgeschlossen.

sandstone and fine-grained conglomerate, interbedded with fine-grained sandstone and siltstone that contain coalified plant fragments. Most of the sandstone horizons show spotted whitish-grey weathering surfaces as well as roundish weathering cavities.

Further up the ridge, above a mafic intrusion (72°08.7' S, 164°39.9' E), a poorly to moderately sorted, mainly clast-supported, unstratified conglomerate is exposed. The dominant clast types are granitic and metamorphic basement rocks up to approximately 20 cm size. It is overlain by an about 25 m thick unit of compositionally similar coarse-grained, crudely stratified conglomerate, which is interbedded with brownish- to greenish-grey sandstone. The overlying deposits, which form the summit of the adjacent peak (72°08.8' S, 164°39.6' E, 2130 m), are made up of whitish to light-grey sandstone, minor conglomerate, and locally thin carbonaceous fine-grained sandstone to siltstone. Although the stratigraphic position of this section is not clear, we assume that it represents the transition from proximal alluvial-fluvial, or possibly fluvio-glacial deposits into the fluvial Takrouna Formation.

West end of the ridge (section NA)

The outcrop investigated appears as a prominent peak in the western part of the ridge (section NA, Tab. 1). At the base of the outcrop, north of the summit, an approximately 50 m thick succession of dark-grey to greenish-grey poorly sorted, matrix-supported conglomerate deposits is dominated by metamorphic and less abundant granitic clasts that are overlain by a Ferrar dolerite sill. These rocks are coarse-grained in the lower part, and predominantly finer-grained in the upper part, grading into grey to black sandy pelite. Interbedded with the fines are poorly sorted pebbly sandstones that are compositionally similar to the underlying deposits. The next unit is characterized by well-sorted whitish to light grey, trough cross-bedded sandstone. The following, approximately 145 m thick section was measured along the eastern ridge of the peak. The lowermost outcrop of the Takrouna Formation at this location shows clast-supported conglomerate with interbedded thin greenish to light-grey sandstone beds. These beds are predominantly coarse- to medium-grained and extend laterally only over a few meters. The conglomerate comprises frequently imbricated cobbles of granitic composition, milky quartz and metamorphic basement clasts. The conglomerate is overlain by pebbly, coarse-grained sandstone with up to 5 m thick cross-bedding sets and erosive base. The major part of the ridge consists of trough cross-bedded units ranging from fine- and medium-grained conglomerate to medium-grained sandstone. Individual units are typically coarse-grained at the base and partly show fining-upward trends on a 1-6 m scale. Locally, the conglomerate-sandstone units are separated by dark-grey, carbonaceous sandstone and minor siltstone, containing some thin coal seams in the lower part of the measured section. The uppermost 15-20 m are coarser-grained than the central and lower part of the section. The measured sections at the Neall Massif indicate relatively consistent mean flow directions towards the WSW.

Lanterman Range

Beacon deposits occur in many small outcrops along the western margin of the Lanterman Range. Although flat-lying sedimentary rocks on top of the basement have been described (Collinson et al. 1986), most of the thicker sections were affected by post-Permian folding and faulting. Therefore long continuous stratigraphic sections in this mountain range are rare.

Only one outcrop in the Lanterman Range could be investigated briefly during a helicopter survey. We selected the southern of two spurs with Beacon deposits north of the Orr Glacier, which exposes a relatively thick and easily accessible section of clastic deposits (Figs. 2 & 8, Tab. 1).

Spur north of the Orr glacier (section LO)

The sedimentary rocks form a slightly irregular syncline with a faulted contact to the basement. The sedimentary succession starts with a basal clast- to matrix-supported conglomerate that contains predominantly granitic components, and a variety of different clasts including meta-sedimentary clasts, quarzites, volcanic and sedimentary lithoclasts. Intercalated sandy units increase upwards in abundance. A coarse- to medium-grained sandy unit showing no stratification but spotted greyish-white weathering surfaces occurs on top of the conglomerate and alternates with units consisting of fine- to medium-grained sandstone. A coarse conglomerate separates the lower part of the outcrop from the upper that mainly consists of relatively homogeneous, whitish to light-grey, medium- to coarse-grained sandstone. Weathering faces typically show a spotted distribution of white and grey colours, and very rough surfaces. The sandstone contains large lens- to layer-shaped grey and brownish concretions, and are locally interbedded with brownish, poorly sorted layers of pebble- and cobble-bearing sandstone.

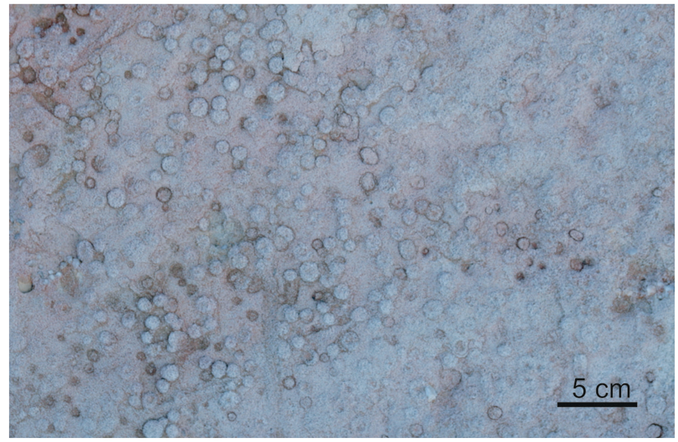

Fig. 7: Bedding plane of a sandstone at Retreat Hills (section RH) showing abundant *Skolithos*-like burrows.

Abb. 7: Schichtfläche eines Sandsteins in den Retreat Hills (Profil RH) mit häufigen *Skolithos*-ähnlichen Grabbauten.

Retreat Hills

Beacon deposits at the Retreat Hills have been mapped (GANOVEX-Team 1987), but were never described in detail. An outcrop of the Takrouna Formation was observed at the southernmost nunatak of the Retreat Hills, and studied during a reconnaissance survey (Figs. 2 & 8, Tab.1).

Southern Peak (section RH)

Predominantly tilted blocks of sedimentary rock form an approximately 10 m thick outcrop. The sedimentary succession starts with coarse-grained pebbly sandstone. The base of the section is covered by snow, but metamorphic basement rocks are exposed at the nunatak north of this outcrop. Notable within this section is the intense bioturbation of all horizons that mainly show pipes of *Skolithos*-like burrows with maxi mum lengths up to 15 cm as well as patchy distributions of black irregular shaped concretions (Fig. 7).

Comparative investigations on Triassic deposits at Vulcan Hill and Timber Peak

Permian and Triassic deposits in northern Victoria Land have been distinguished by the occurrence of *Glossopteris*- and *Dicroidium*-bearing floras, respectively, as well as by the compositional differences of the sandstones (Collinson et al. 1986, Tessensohn & Mädler 1987). The sedimentological features of the sandstones, however, were described as comparatively similar (Collinson & Kemp 1983). The Triassic deposits in North Victoria Land were studied in detail during GANOVEX IX (Schöner et al. 2011, Bomfleur et al. 2011). Two key outcrops at Timber Peak and Vulcan Hills were re-visited briefly during reconnaissance surveys for additional sampling, gathering of further paleocurrent data, and for re-investigation of sedimentological details in comparison with the Permian deposits (Tab. 1). Both sections are dominated by medium- to coarse-grained sandstones, which are partly whitish to light-grey and quartz-rich, and partly greenish-grey and rich in rock fragments. Fine-grained deposits interbedded with the sandstones at both sections contain *Dicroidium*-bearing macrofloras, which were already described by Tessensohn & Mädler (1987) and Gair et al. (1965).

DISCUSSION

The overall depositional setting of the Takrouna Formation has been described as low sinuosity braided streams (Walker 1983, Collinson et al. 1986), draining towards the coast located in present-day Tasmania. Results of the present study confirm that the Takrouna Formation has been deposited in a large fluvial drainage system dominated by braided stream deposits. A large-scale, overall fining-upward grain size evolution is evident especially from the continuous section at the Morozumi Range. This general trend is interrupted by two smaller scale coarsening-up trends, terminating in sheet-like coarse-grained sandstone bodies in the central part and at the top of the studied succession. Compared to the section studied at DeGoes Cliff in the Morozumi Range, coarser-grained facies appear in the eastern part of the study area (Alamein Range, Neall Massif), whereas a generally finer-grained succession is present in the westernmost section (Helliwell Hills). Similar regional sedimentological variations have already been noted by Collinson et al. (1986) and Walker (1983). Based on the facies distribution and the paleocurrent patterns the easternmost section was most likely deposited proximal to the eastern margin of the sedimentary basin, whereas the westernmost sections probably represent a position close to the basin axis. At the basin margin the river system appears to have remained highly energetic with a low potential to preserve fine-grained deposits such as fine- to medium-grained sandstones, siltstones, organic rich mudstones and occasionally coal. Towards the basin axis the depositional environment is more variable, showing a pronounced development of the units mentioned above.

The syn-Permian tectonic features described by Walker (1983) at DeGoes Cliff in the Morozumi Range could be verified. No indications for syn-depositional faulting were observed at any of the investigated outcrops of the Takrouna Formation. Our field results suggest that at least the sections located in the central part of basin can be correlated lithostratigraphically, but this has to be verified by further petrographic investigations.

CONCLUSIONS

During the expedition GANOVEX X four complete and several detailed sections could be logged within the six different mountain ranges in the northern part of northern Victoria Land (Fig. 8). This enables the recognition of the distribution of different lithofacies types that allows a distinction of more proximal and distal parts of the fluvial system of the Takrouna Formation. Coarse-grained successions that comprise minor variation in fluvial style were probably deposited close to the basin margin. Sedimentary successions showing a great variety of facies, grain size and fluvial architecture more likely represent locations close to the basin axis. Further conclusions regarding the depositional evolution of the fluvial system, the lithostratigraphic framework and possible tectonic as well as climatic controls on sedimentation will be drawn based on further petrographical and geochemical analysis of the sedimentary rocks. These investigations will focus on sediment provenance and diagenesis.

ACKNOWLEDGMENTS

We thank the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR, Hannover) for inviting us to join the expedition GANOVEX X and for the logistical support during the expedition. We are grateful to Franz Tessensohn (BGR), Ricarda Hanemann (University Jena), Andreas Läufer (BGR) and Frank Lisker (University Bremen) for sharing their field experience from former GANOVEX expeditions, which helped us to prepare the field campaign and to select the most promising sedimentary sections. We are most thankful to Mike Atkinson (Christchurch), who was not only an excellent field guide but also helped us to collect many samples of the Permian *Glossopteris*-bearing horizons. We kindly acknowledge the work of the pilots Steve, Phil, Carl and Jamie and the engineer Jim of Helicopters New Zealand (Nelson), who safely transported us to all essential localities, and were patient with us when field work took longer and samples were heavier than originally planned. We thank Franz Tessensohn and Frank Lisker for their helpful review comments, which improved the manuscript. The research project is supported by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), grant SCHO 1269/1-1, and is part of the DFG research program SPP 1158 (Antarctic research and comparative studies in Arctic sea ice areas).

References

Barrett, P.J. (1991): The Devonian to Jurassic Beacon Supergroup of the Transantarctic Mountains and correlatives in other parts of Antarctica.- In: R.J. Tingey (ed), The Geology of Antarctica, Oxford University Press, Oxford: 120-152.

Bomfleur, B., Schneider, J., Schöner, R., Viereck-Goette, L. & Kerp. H. (2011): Fossil sites in the continental Victoria and Ferrar groups (Triassic–Jurassic) of North Victoria Land, Antarctica.- Polarforschung 80: 88-99.

Collinson, J.W. & Kemp, N.R. (1983): Permian-Triassic sedimentary sequence in northern Victoria Land, Antarctica.- In: R.L. Oliver, P.R. James & J.B. Jago (eds), Antarctic Earth Science, Australian Academy of Science, Canberra: 221-225.

Collinson, J.W., Pennington, C.D. & Kemp, N.R. (1986): Stratigraphy and petrology of Permian and Triassic fluvial deposits in northern Victoria Land, Antarctica.- In: E. Stump (ed), Geological Investigations in Northern Victoria Land, Antarctic Research Series 46: 211-242.

Collinson, J.W., Isbell, J.L., Elliot, D.H., Miller, M.F., Miller, J.M.G. & Veevers, J.J. (1994): Permian-Triassic Transantarctic Basin.- In: J.J. Veevers & C.M. Powell (eds), Permian-Triassic Pangean basins and foldbelts along the Panthalassan margin of Gondwanaland, Geol. Soc. Amer. Mem. 184: 173-222.

Dow, J.A.S. & Neall, V.E. (1974): Geology of the lower Rennick Glacier, northern Victoria Land, Antarctica.- New Zealand J. Geol. Geophys. 17: 659-714.

Gair, H.S., Norris, G. & Ricker, J. (1965): Early Mesozoic microfloras from Antarctica.- New Zealand J. Geol. Geophys. 8: 231-235.

GANOVEX-Team (1987): Geological Map of North Victoria Land, Antarctica, 1:500 000 - Explanatory Notes.- Geol. Jb. B 66: 7-79.

Laird, M.G. & Bradshaw, J.D. (1981): Permian tillites of North Victoria Land, Antarctica.- In: M.J. Hambrey & W.B. Harland (eds), Earth's pre-Pleistocene glacial record, Cambridge Univ. Press, London: 237-240.

Tessensohn, F. & Mädler, K. (1987): Triassic plant fossils from North Victoria Land, Antarctica.- Geol. Jb. B 66: 187-201.

Schöner, R., Viereck-Götte, L., Schneider, J. & Bomfleur, B. (2007): Triassic-Jurassic sediments and multiple volcanic events in North Victoria Land, Antarctica: A revised stratigraphic model.- In: A.K. COOPER & C.R. RAYMOND (eds), Antarctica: A Keystone in a Changing World. Online Proceedings of the 10th ISAES, USGS Open-File Report 2007-1047, Short Res. Paper 102: 1-5.

Schöner, R., Bomfleur, B., Schneider, J. & Viereck-Götte, L. (2011): A systematic description of the Triassic to Lower Jurassic Section Peak Formation in North Victoria Land (Antarctica).- Polarforschung 80: 71-87.

Skinner, D.N.B. (1981): Possible Permian glaciation in north Victoria Land, Antarctica.- Geol. Jb. B 41: 261-266.

USGS-LIMA (2009): http://lima.usgs.gov. Publication date 04/2009.

Viereck-Goette, L., Schöner, R., Bomfleur, B. & Schneider, J. (2007): Multiple shallow level sill intrusions coupled with hydromagmatic explosive eruptions marked the initial phase of Ferrar Magmatism in north Victoria Land, Antarctica.- In: A.K. COOPER & C.R. RAYMOND (eds), Antarctica: A Keystone in a Changing World. Online Proceedings of the 10th ISAES, USGS Open-File Report 2007-1047, Short Res. Paper 104: 1-5.

Walker, B.C. (1983): The Beacon Supergroup of northern Victoria Land, Antarctica.- In: R.L. OLIVER, P.R. JAMES & J.B. JAGO (eds.), Antarctic Earth Science. Australian Acad. Scie., Canberra: 211-214.

Fig. 8: Simplified overview of the lithological columns of the investigated sections. AC = Monte Cassino, AL = unnamed peak 10 km northwest of Takrouna Bluff, AM = Moawhango Névé, AR = Northern Alamein Range cliff, BT = Plateau directly north of Boggs Valley, BV = Boggs Valley, LO = Spur north of the Orr glacier, MR = DeGoes Cliff, MT = Plateau northwest of DeGoes Cliff, NA = West end of Neall Massif ridge, NJ = Central part of Neall Massif ridge, NM = East end of Neall Massif ridge, RH = southern peak of Retreat Hills.

Abb. 8: Vereinfachte Übersicht über die lithologische Abfolge der untersuchten Profile. AC = Monte Cassino, AL = unbenannter Berg 10 km nordwestlich des Takrouna Bluff, AM = Moawhango Névé, AR = Nördliches Kliff der Alamein Range, BT = Plateau unmittelbar nördlich von Boggs Valley, BV = Boggs Valley, LO = Felsrücken nördlich des Orr Glacier, MR = DeGoes Cliff, MT = Plateau nordwestlich von DeGoes Cliff, NA = westliches Ende des Felsrückens im Neall Massif, NJ = zentraler Teil des Felsrückens im Neall Massif, NM = östliches Ende des Felsrückens im Neall Massif, RH = südlicher Felsgipfel der Retreat Hills.

Fig. 8 / Abb. 8 continued ▶

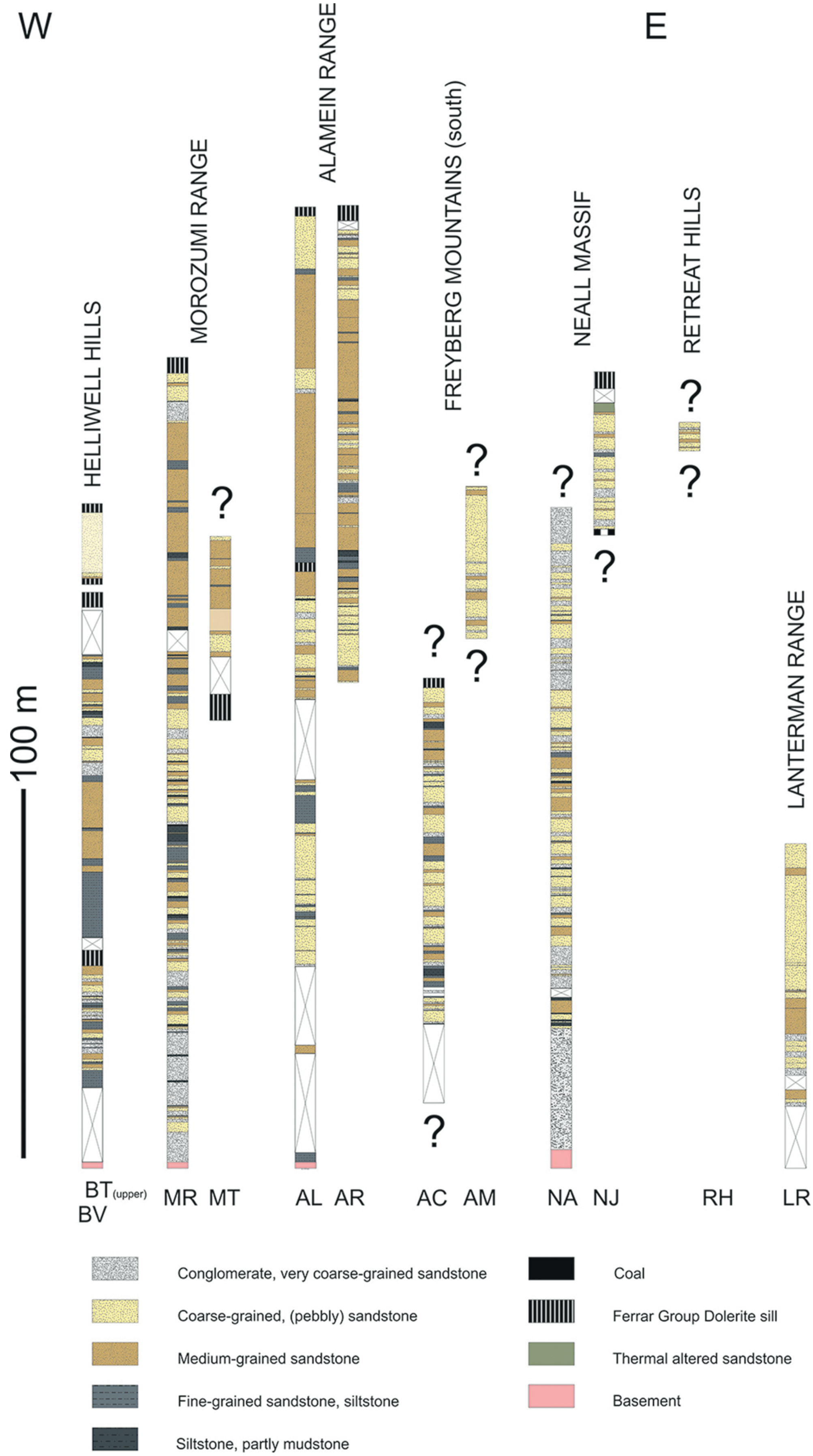
W
E
HELLIWELL HILLS
MOROZUMI RANGE
ALAMEIN RANGE
FREYBERG MOUNTAINS (south)
NEALL MASSIF
RETREAT HILLS
LANTERMAN RANGE
100 m
BT(upper)
BV
MR
MT
AL
AR
AC
AM
NA
NJ
RH
LR
Conglomerate, very coarse-grained sandstone
Coarse-grained, (pebbly) sandstone
Medium-grained sandstone
Fine-grained sandstone, siltstone
Siltstone, partly mudstone
Coal
Ferrar Group Dolerite sill
Thermal altered sandstone
Basement

Fig. 8 / Abb. 8