

# Field Studies of Sedimentary Sequences in Eastern Hurd Peninsula Central Livingston Island, South Shetland Islands

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**Abstract:** The sedimentary sequences outcropping in Hurd Peninsula, Livingston Island, are formally defined as members of the Miers Bluff Formation (MBF): Johnsons Dock and Napier Peak Members and Moores Peak breccias. The lowermost strata (Johnsons Dock Member) are studied in detail, while the investigations of the upper part of the sedimentary sequences cropping out at Napier Peak and Cerro Mirador are of a reconnaissance nature only. The sediments in eastern Hurd Peninsula are studied in three sedimentological and geological sections (Napier Peak, Cerro Mirador and Moores Peak). Measurements of the orientation of the axes of small-scale folds represented in the sections suggest that phases 3a and 3b of MUÑOZ et al. (1992) can be unified in one final phase. Their orientations are in the frame of normal deviations usually within the development of a fold system. The Moores Peak breccias are a component and an inseparable part of the whole sedimentary sequence in Hurd Peninsula. They are the upper lithostratigraphical division of the MBF and represent the final stage of sedimentation in the Carboniferous(?)–Triassic Miers Bluff depositional basin. The dominant transport of the Moores Peak breccias has been by debris flows.

**Zusammenfassung:** Die Sedimentgesteinsserien der Hurd Peninsula, Livingston Island, sind formal als Untereinheiten der Miers Bluff-Formation (MBF) definiert: Johnsons Dock-Schichtglied, Napier Peak-Schichtglied und Moores Peak-Brekzie. Die unterste Einheit (Johnsons Dock-Schichtglied) wird vollständig beschrieben, während die Bearbeitung des höheren Teils der Abfolge am Napier Peak und Cerro Mirador erst Erkundungscharakter hat. Die Gesteine im Ostteil der Hurd Peninsula werden in drei sedimentologischen und geologischen Profilen dargestellt (Napier Peak, Cerro Mirador und Moores Peak). Messungen der Achsenrichtungen von Kleinfalten legen nahe, die von MUÑOZ et al. (1992) beschriebenen Faltungsphasen 3a und 3b als eine einzige abschließende Phase zu betrachten. Ihre Richtungen liegen im Rahmen der üblichen Schwankungen eines Faltungsereignisses. Die Moores Peak-Brekzien bilden einen integralen und untrennbaren Bestandteil der gesamten sedimentären Abfolge auf Hurd Peninsula. Sie sind der oberste lithostratigraphische Teil der MBF und stellen das Endstadium der Sedimentation im Ablagerungsraum der karbonisch(?)–triassischen Miers Bluff-Formation dar. Überwiegende Transportart der Moores Peak-Brekzien waren Schuttströme.

## INTRODUCTION

The sedimentary sequences outcropping in Hurd Peninsula, Livingston Island, form part of the basement of the South Shetland Islands. They form an important part of the Mesozoic-Cenozoic magmatic arc (SMELLIE et al. 1984). They are formally defined as Miers Bluff Formation (MBF) and Moores Peak breccias (SMELLIE et al. 1995) or Moores Peak Formation (WILLAN 1996). The MBF is divided into the Johnsons Dock and Napier Peak Members (SMELLIE et al. 1995). These lithostratigraphical di-

visions are fully correlated with Unit 1 and Unit 2 of PALLAS et al. (1992) (Fig. 1). DOKTOR et al. (1994) proposed to restrict the name MBF to the lowermost Unit 1 of PALLAS et al. (1992), equivalent to Johnsons Dock Member of SMELLIE et al. (1995). The removal of the outcrops in eastern Hurd Peninsula from the MBF, however, is not supported by our observations; therefore the scheme of SMELLIE et al. (1995) is used in this study.

The depositional age of the MBF was poorly constrained for a long time. No diagnostic fossils had been found, but some results of isotope geochronology on detrital zircons from turbiditic sandstones and the clay-fraction suggested a wide interval between late Carboniferous(?) and early Jurassic (SMELLIE et al. 1984, MILLER et al. 1987, HERVÉ 1992, HERVÉ et al. 1991, WILLAN et al., 1994). Recent discovery of a rich palynoflora in the Johnsons Dock Member helps now to date this unit as Norian to Rhaetian (YAN-BIN et al. 1999). The volcanoclastic rocks of the Mount Bowles Formation probably overlies the MBF unconformably (SMELLIE et al. 1995).

For the structure of the MBF, DALZIEL (1972) proposes overturning of the strata as a result of a tight, several-km-scale fold with an axial plane dipping to the WNW. MUÑOZ et al. (1992) and SMELLIE et al. (1995) interpret the MBF as being deformed by polyphase folding with overturned beds dipping slightly to the NW. They identify three folding phases.

The lowermost strata of the MBF (Johnsons Dock Member) are shown in detail in four stratigraphic sections situated close to the Spanish base „Juan Carlos I“ (PALLAS et al. 1992). The investigations of the upper part of the sedimentary sequence cropping out at Napier Peak and Cerro Mirador were of a reconnaissance nature; detailed field data are also lacking in previous works. A geological cross section and a sketch map of Moores Peak are given in WILLAN'S (1996) study recently.

The main questions remaining to be resolved, are the origin and affinities of the Moores Peak breccias. They could be part of the MBF, a basal unit of the Mount Bowles Formation, a younger unrelated unit (SMELLIE et al. 1995), or form part of the mid to late Cretaceous Antarctic Peninsula Volcanic Group (WILLAN 1996).

In this paper new stratigraphical and structural data for the sediments in eastern Hurd Peninsula are presented, that confirm the Moores Peak breccias as uppermost part of the MBF and will

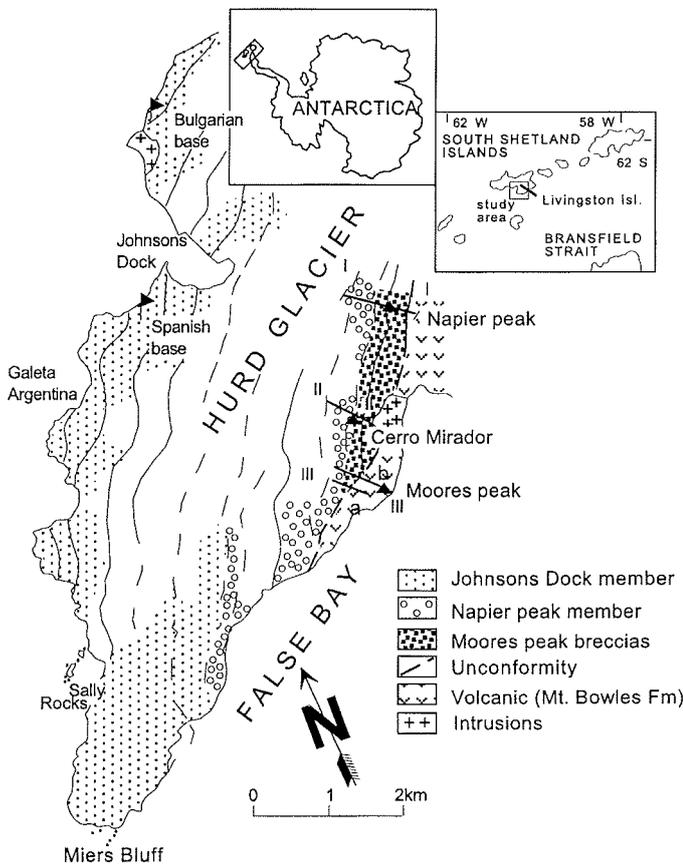
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be useful for the future understanding of the evolution of the Miers Bluff depositional basin.

## OUTCROP CHARACTERISTICS

The sedimentary rocks in eastern Hurd Peninsula are distributed from north to south in three main outcrops: Napier Peak, Cerro Mirador and Moores Peak (Fig. 1). They generally consist of intercalated mudstones and fine sandstones, thick massive medium sandstones, muddy and sandy conglomerates, breccioconglomerates and massive cobble to boulder breccias. The sediments are studied at three sedimentological and three geological sections (Figs. 2, 3). The numerous dykes cutting the sedimentary sequence are not considered here.



**Fig. 1:** Sketch map of the lithostratigraphical units at Hurd Peninsula (after PALLAS et al. 1992, and SMELLIE et al. 1994). I-I: Sedimentological and geological sections at Napier Peak; II-II: Sedimentological and geological sections at Cerro Mirador; IIIa-IIIb: Sedimentological and geological sections at Moores Peak.

**Abb. 1:** Die lithostratigraphischen Einheiten auf Hurd Peninsula (nach PALLAS et al. 1992 und SMELLIE et al. 1994). I-I: Sedimentologisches und geologisches Profil am Napier Peak. II-II: Sedimentologisches und geologisches Profil am Cerro Mirador IIIa-IIIb: Sedimentologisches und geologisches Profil am Moores Peak.

The three sections are oriented NW-SE; they are situated on the overturned limb of a big, several-km-wide fold with a NE-SW trending axis. Most of the measured bedding planes dip steeply to the NW and are overturned, while those that dip to the SE are in normal position (Fig. 3). The normal position of the beds is observed near the base of Moores Peak breccias in the up-

permost parts of all sections. The variations in inclination of the strata depend on well presented parasitic folds with subhorizontal axial planes. The sequence can be related to the Napier Peak Member and Moores Peak breccias of SMELLIE et al. (1995).

## Napier Peak

The sedimentary rocks at Napier Peak consist of mudstones interbedded with thin fine sandstones, amalgamated massive fine to medium sandstones, mudstones with scattered well rounded pebbles of quartz, sandstone and granitoids, intraformational lenticular beds and irregular lenses of pebble to cobble matrix-supported conglomerates with well rounded clasts of quartz, sandstone, granitoids and subrounded clasts of mudstones (Fig. 2). The described lithological varieties are typical for the lower and middle part of the section, and possibly these sediments are to be included in the Napier Peak Member of SMELLIE et al. (1995). Most of the thin-bedded sandstones are of turbiditic origin characterized by internal features including graded bedding, convolute, cross and parallel lamination. Some of the coarse beds have channelized bases (Fig. 2). Slumping also occurs. The upper part of the sequence consists of thin beds of mudstones, thick massive medium grained sandstones, irregular lenses and lenticular beds of pebbly to cobbly conglomerates with well rounded clasts of sandstone, quartz and granitoids. Massive breccio-conglomerates and breccias with subangular to subrounded mudstone clasts parallel to the bedding and well rounded sandstone, quartz and granitoid clasts are also present. The breccio-conglomerate, breccia and conglomerate are predominantly silty-sandy matrix-supported. The lower contacts are erosive and channelized. The sediments of the uppermost part of the section show some distinctive features described from the Moores Peak breccias of SMELLIE et al. (1995). The upper contact of the sedimentary sequence to the volcaniclastic rocks of the Mount Bowles Formation is sharp (Figs. 2, 3).

## Cerro Mirador

The sedimentary rocks outcropping at Cerro Mirador represent one of the best continuous sedimentary sequences in eastern Hurd Peninsula (Figs. 2, 3). They consist of interbedded mudstones and thin fine sandstones, thick massive amalgamated fine to medium sandstones, pebbly conglomerates and breccio-conglomerates with abundant muddy and silty-sandy matrix, and thick massive cobble to boulder breccias (Fig. 2). The clasts in the conglomerates are well rounded quartz, sandstone and rare granitoid pebbles. One irregular block (olistolith?) of massive fine sandstone was found in the lowermost part of the section (Fig. 2). Sedimentary textures as cross, parallel and convolute lamination are present in the intercalated mud-sand couplets. The massive amalgamated sandstones form units up to 15 m thick. The breccias occupy the uppermost part of the sequence. They consist of subangular cobble to boulder size sandstone and mudstone clasts. Rare well-rounded quartz pebbles are scattered in the sandy-muddy matrix. Some of the lower bases of the beds

are channelized. The uppermost part shows distinctive features characteristic of the Moores Peak breccias of SMELLIE et al. (1995). This coarse sedimentation is closely related with the deposition of the underlying sediments and represents an up-

up to 5 m thick blocks of massive medium sandstones (olistoliths?) are scattered in the interbedded mudstones and fine sandstones (Fig. 2-IIIa). The breccia clasts are ranging from pebbles to large, up to 10 m thick packages of massive fine to medium

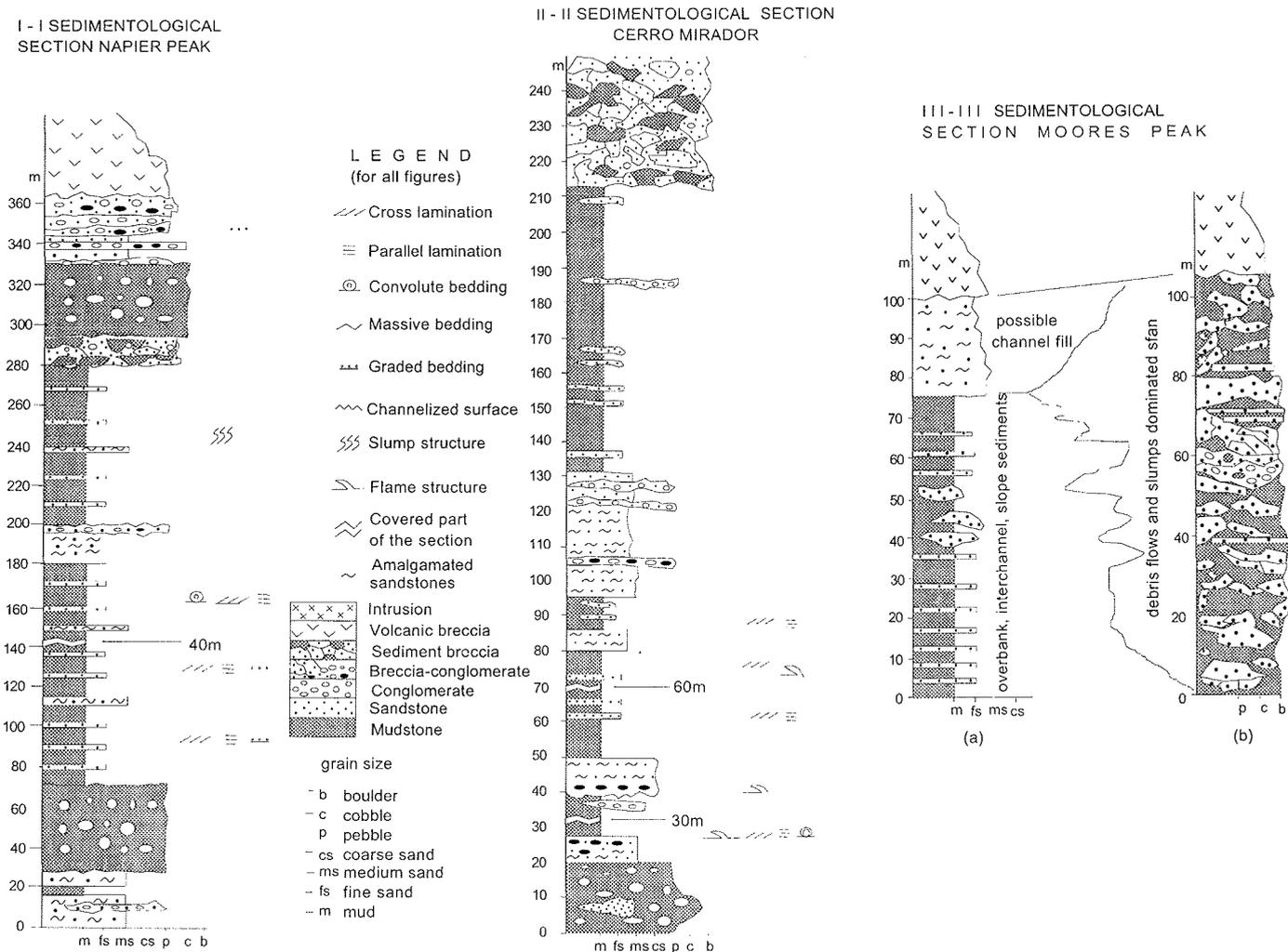


Fig. 2: Sedimentological sections at Napier Peak I-I, Cerro Mirador II-II and Moores Peak IIIa-IIIb.

Abb. 2: Sedimentologische Profile am Napier Peak I-I, Cerro Mirador II-II und Moores Peak IIIa-IIIb.

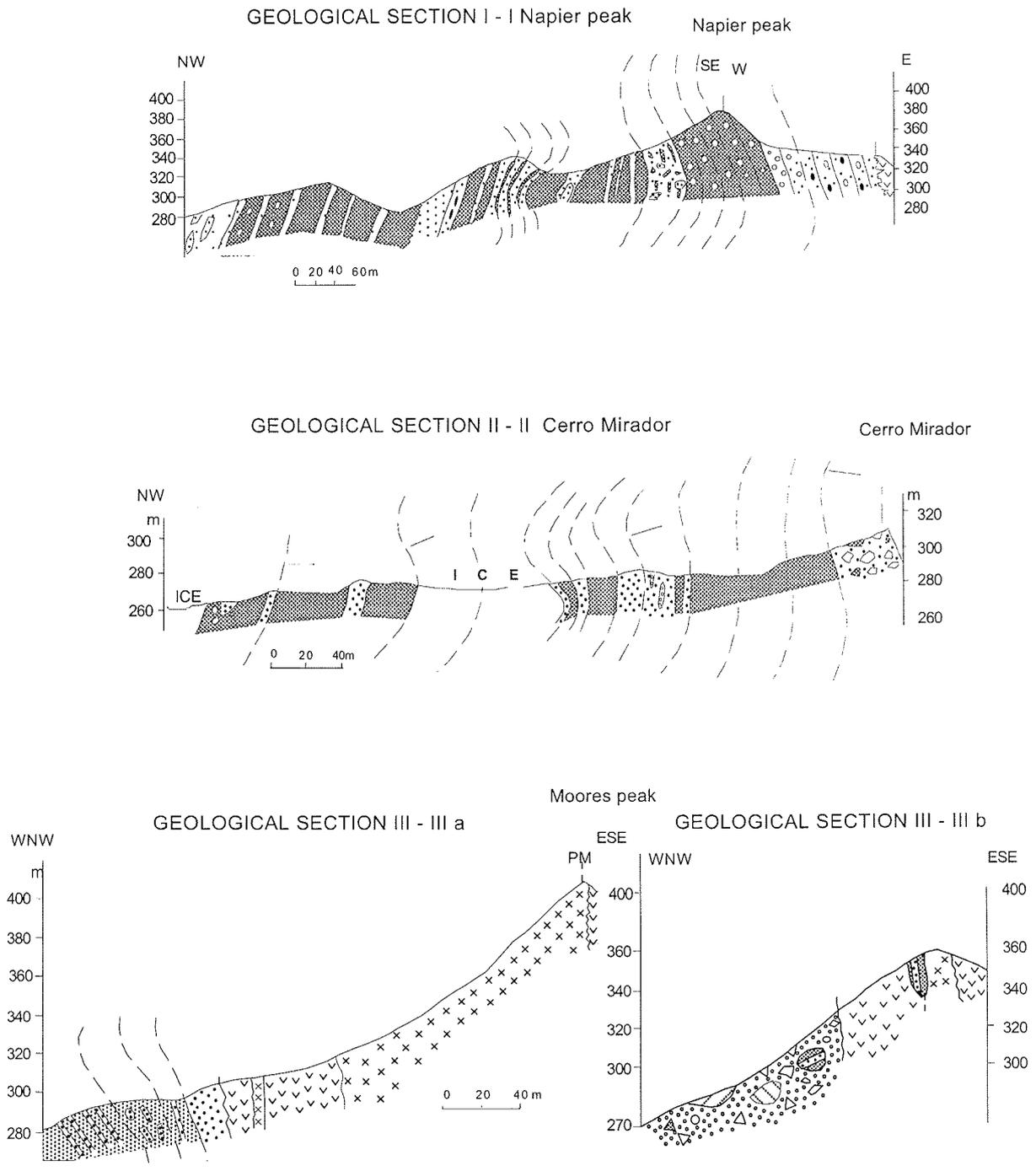
per part of one continual progradational sequence. The lower and middle parts of the described sedimentary succession can possibly be correlated with the same parts of the Napier Peak section (Fig. 2).

### Moores Peak

The Moores Peak is the largest ice-free area in eastern Hurd Peninsula. The volcanoclastic rocks of Mount Bowles Formation, intrusions and numerous dykes are widespread (WILLAN 1996). The best exposure of sedimentary rocks is situated 400 m west of Moores Peak (Fig. 1). The sequence consists of intercalated mudstones and thin fine sandstones, as well as thick massive amalgamated fine to medium sandstones (Fig. 2-IIIa) and thick massive sedimentary breccias (Fig. 2-IIIb). Irregular

sandstones and mudstone-sandstone strata. The quartz, sandstone and rare volcanic pebbles are usually rounded and form conglomerate lenses. The coarse chaotic sediments have a silty-sandy or muddy matrix and are rarely clast supported. Channelized bed surfaces are common. We interpreted these sediments as debrite and slump deposits (STOW 1994). The upper contact of the described sequence to the volcanic breccias of Mount Bowles Formation is sharp (Figs. 2, 3). The complicated „transition zone“ of SMELLIE et al. (1995) and WILLAN (1996) is a lowermost part of the volcanoclastic Mount Bowles Formation.

The sedimentary breccias that crop out at Moores Peak are the uppermost, coarsest and most composite part of the whole sedimentary sequence in eastern Hurd Peninsula.



**Fig. 3:** Geological sections at Napier Peak I-I, Cerro Mirador II-II and Moores Peak III-IIIa,b.

**Abb. 3:** Geologische Profile am Napier Peak I-I, Cerro Mirador II-II und Moores Peak III-IIIa,b.

**CONCLUSIONS**

The new sedimentological and structural studies in eastern Hurd Peninsula have improved our understanding of the upper part of the Miers Bluff Formation:

1.) The systematic record of bedding planes on three geological sections (Fig. 3) shows that they are situated in an overturned fold limb of a big several km scale tight fold. The hinge of the

fold is orientated NE-SW, the axial plane dips steeply to the NW. The outlines of the parasitic folds (Fig. 3) show that the limb is overturned. Typical structures on the lower bed surfaces (flame structures, load casts etc.) in the studied sections clearly indicate younging direction of the bedding towards the SE. Most individual beds are overturned and dip to the NW. The local variations in the orientation of the bedding planes are the result of various scale parasitic folds. When the strata dip to the SE they show normal bedding. Our structural observations co-

incide with the results of DALZIEL (1972). Analyzed measurements of the orientation of the axes of the small-scale folds represented in the three studied geological sections suggest that phases 3a and 3b of MUÑOZ et al. (1992) can be viewed as one final phase. The orientations of the axes are in the frame of normal deviations within of a fold system.

2.) The Moores Peak breccias do not form part of the volcanic Mount Bowles Formation or younger units. They are a continuous and inseparable part of the pre-Cretaceous sedimentary sequence in Hurd Peninsula. The Moores Peak breccias are clearly the upper lithostratigraphical division of the MBF. They represent the final stage of sedimentation in the Carboniferous(?)–Triassic Miers Bluff depositional basin.

3.) The dominant transport mechanism for the Moores Peak breccias probably was by debris flows as a final stage of deposition in a turbidite system, formed along the trench of the converging Pacific margin of Gondwana during the Early Mesozoic (ARCHE et al. 1991). Debris-flow deposits typically are massively textured, poorly sorted, matrix supported mixtures of sediment ranging in size from clay to cobbles and m-thick boulders (FISHER 1971, COSTA 1984, MAJOR 1997). Such sedimentological features are described from the Moores Peak breccias. Future detailed sedimentological studies will reveal more exactly the depositional environments of this facies still undescribed in the Trinity Peninsula Group.

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