POLISH POLAR RESEARCH	9	4	505—519	1988

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Report on the Polish geological investigations in the Antarctic Peninsula sector, 1987—1988

ABSTRACT. Geological investigations of the 3rd Polish Geodynamic Expedition to West Antarctica, 1987—1988, covered the following topics: sedimentological and mesostructural studies of the Trinity Peninsula Group (?Carboniferous — Triassic) at Hope Bay, Cape Legoupil and Andvord Bay, Antarctic Peninsula, and at South Bay, Livingston Island (South Shetland Islands); late Mesozoic plant-bearing terrestrial sediments at Hope Bay; Antarctic Peninsula Volcanic Group, Andean-type plutons and systems of acidic and basic dykes (Upper Cretaceous and ?Tertiary) at Trinity Peninsula and around Gerlache Strait (Arctowski Peninsula, Anvers and Brabant islands); basalts and hyaloclastites within Tertiary glacigenic successions of King George Island; volcanic succession of the Deception Island caldera.

Key words: West Antarctica, regional geology, stratigraphy, tectonics, sedimentology, volcanology.

Introduction

The Polish geological investigations in the Antarctic Peninsula sector carried out during the austral summer of 1987—1988 formed a part of scientific programme of the 3rd Polish Geodynamic Expedition to West Antarctica led by Professor Aleksander Guterch. The expedition programme included, moreover, deep-seismic sounding of the Antarctic lithosphere, stationary recording of seismic activity in the area, seismoacoustic profiling and sampling of sea-bottom sediments. This was a direct continuation of the programmes carried out during the first (1979—1980) and the second (1984—1985) Polish Geodynamic Expeditions to West Antarctica organized by the Polish Academy of Sciences (*see* Guterch *et al.* 1985; Birkenmajer 1987).

The geological party led by the present author consisted of two independently working groups. The first group included Prof. Krzysztof Birkenmajer

(leader), Dr Krzysztof Görlich, Dr Antoni K. Tokarski, Władysław Danowski and Eng. Krzysztof Rolnicki. The group boarded the Polish ship M/S "*Jantar*" in Buenos Aires on December 4, 1987. It carried out geological investigations in Antarctica between December 23, 1987 and February 23, 1988, in the following areas: Elephant Island, King George Island, Livingston Island and Deception Island (South Shetland Islands); Hope Bay and Cape Legoupil (Trinity Peninsula); western coasts of Gerlache Strait — Brabant Island, Anvers Island; eastern coasts of Gerlache Strait — Arctowski Peninsula, Andvord Bay and Paradise Harbour (Danco Coast); Neumayer Channel, Schollaert Channel and Melchior Archipelago. The field work completed, the group returned on March 3, 1988 on board M/S "*Jantar*" to Buenos Aires, from where it flew back home.

The second group consisted of Docent Andrzej Gaździcki (group leader), Dr Marek Doktor and Dr Szczepan J. Porębski. The group flew to Buenos Aires at the beginning of January, 1988, where it joined a geological party from Instituto Antártico Argentino. Together, they flew to the Argentine Base *Vicecomodoro Marambio* on Seymour Island (North-east Antarctic Peninsula) where, during six weeks, they carried out palaeontological, stratigraphical and sedimentological studies in Early Tertiary and Late Cretaceous sedimentary sequences. The group returned to Buenos Aires in time to meet M/S "*Jantar*" and join the members of the scientific team of the 3rd Polish Geodynamic Expedition on their way home. A report of joint Argentine-Polish geological and palaeontological work on Seymour Island is being presented separately by A. Gaździcki and co-workers (*see*: Doktor *et al.* 1988).

Geological mapping

Geological mapping represented an important element of the field work in the Hope Bay area (northern tip of Antarctic Peninsula), along the eastern and western coasts of Gerlache Strait (Arctowski Peninsula, and Palmer Archipelago, respectively), and on Deception Island (Fig. 1).

(1) Hope Bay, Trinity Peninsula (Antarctic Peninsula: Fig. 1: *2*). Geological maps to scales 1:25,000 (25 km^2) and 1:10,000 (15 km^2) covered the following lithostratigraphic units: turbidite clastic sequence of the Trinity Péninsula Group (?Carboniferous — Permian?); fresh-water plant-bearing clastics of the Mount Flora Formation (Jurassic); predominantly acidic stratiform volcanics and volcaniclastics of the Kenney Glacier Formation (?Lower Cretaceous), post-dating Jurassic plant-bearing beds of the Mount Flora Formation; Andean gabbroic, dioritic and granitoid plutons (?Upper Cretaceous); acidic and basic dykes and sills (?Upper Cretaceous and ?Tertiary)

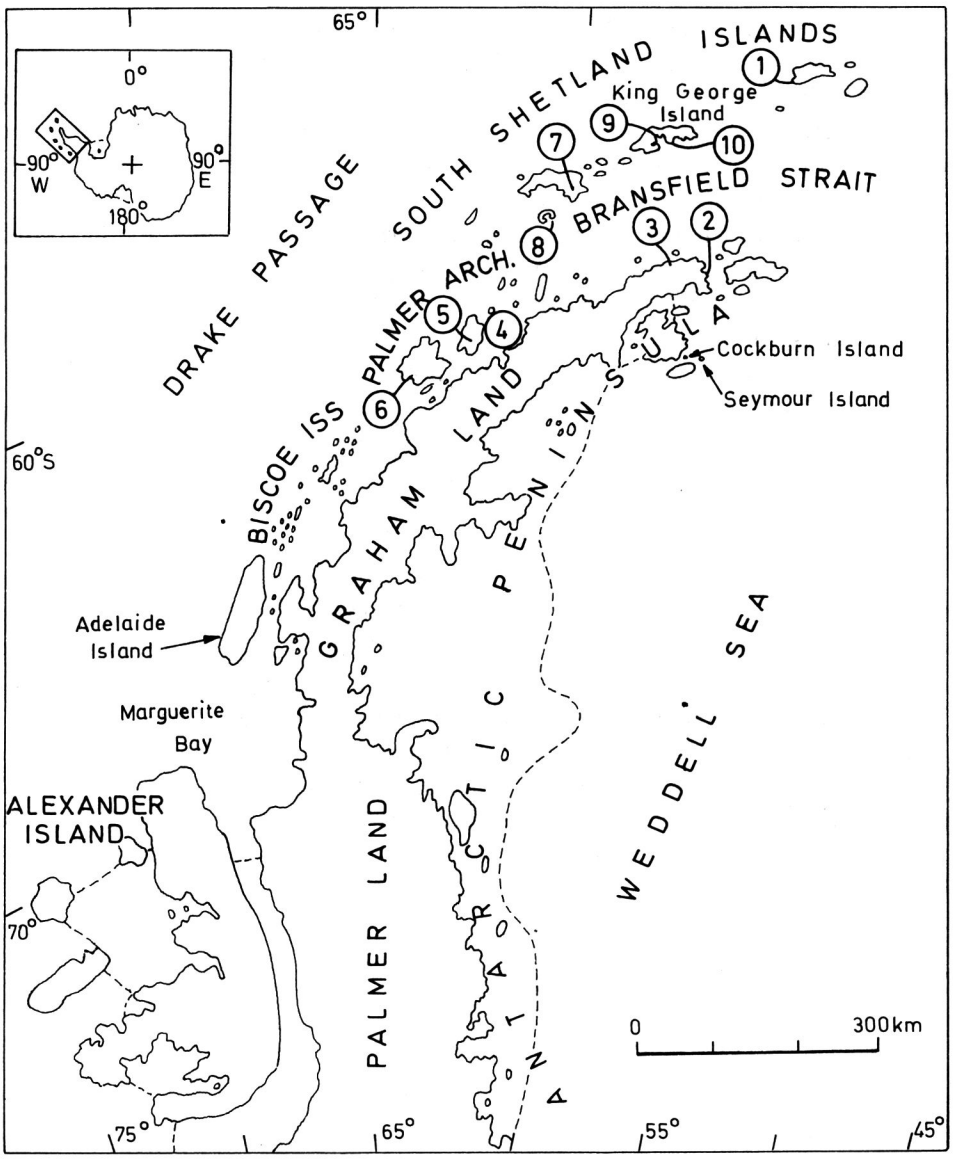

Fig. 1. Key maps to show location of geological investigations of the 3rd Polish Geodynamic Expedition to West Antarctica, 1987—1988, in the Antarctic Peninsula sector, and in Antarctica (inset). 1 — Elephant Island, Stinker Point; 2 — Hope Bay, 3 — Cape Legoupil, 4 — Gerlache Strait (Arctowski Peninsula and vicinity), 5 — Brabant Island, 6 — Anvers Island, 7 — Livingston Island (Hurd Peninsula), 8 — Deception Island, 9 — King George Island, Admiralty Bay, 10 — King George Island, King George Bay

cutting through the whole, or a part of, the sedimentary and magmatic successions mentioned above; Quaternary deposits. The geological mapping has been carried out by K. Birkenmajer.

(2) Deception Island, South Shetland Islands (Fig. 1: *8*). Geological maps to scales of 1:50,000 (180 km^2), 1:25,000 (15 km^2) and 1:12,500 (15 km^2) have been prepared by K. Birkenmajer. The map to 1:50,000 scale covered the whole area of the volcano, including its pre-caldera and post-caldera formations. More detailed maps have covered selected areas of Whalers Bay and Telefon Bay.

(3) Vicinity of Chilean Base *General Bernardo O'Higgins*, at Cape Legoupil, Schmidt Peninsula (Antarctic Peninsula), Kopaitic and Gandara islands (Fig. 1: *3*). The mapping was carried out by A. K. Tokarski along with mesostructural studies in marine clastics of the Cape Legoupil Formation (Trinity Peninsula Group) of Triassic age (*cf.* Thomson 1975).

(4) Vicinity of the Spanish Base *Juan Carlos I* on Hurd Peninsula, South Bay (Livingston Island, South Shetland Islands — Fig. 1: *7*). The mapping was carried out by A. K. Tokarski along with mesostructural studies in clastic sediments of the Miers Bluff Formation (Trinity Peninsula Group).

(5) Coasts of Gerlache Strait: from Arctowski Peninsula, northern tip, to Andvord Bay (Danco Coast, Antarctic Peninsula) in the east; Neumayer Channel and eastern coasts of Anvers Island and Brabant Island (Palmer Archipelago) in the west (Fig. 1: *4—6*). The mapping to the scale of 1:125,000 (about 2000 km^2) covered the following lithostratigraphic complexes: Antarctic Peninsula Volcanic Group (APVG) lavas and volcaniclastics (probably Lower Cretaceous); Andean granitoid plutons (Upper Cretaceous and Early Tertiary); leucocratic and melanocratic dyke swarms post-dating the above mentioned rock-complexes. The mapping was carried out by K. Birkenmajer.

Succession and age of rocks

(1) Trinity Peninsula Group

Stratigraphic succession of the Hope Bay Formation (*cf.* Hyden and Tanner 1981; Smellie 1987) has been studied in the Hope Bay area by K. Birkenmajer. The formation is here gently folded, occasionally faulted, with the oldest units in the east, near Tabarin Peninsula, younging towards the west, in the direction of Scar Hills. This is a predominantly turbidite sequence with a wealth of sedimentary structures preserved mainly inside amalgamated homogenous sandstone beds, such as asymmetric, often load-casted current ripples, submarine slumps, shale-clast breccias etc. (Fig. 2A-D). Surface markings of inorganic and organic origin are seldom preserved, probably mainly due to strong compaction and partial recrystallization of the clastic complex. Directional structures indicate clastic supply from eastern and north-eastern sources.

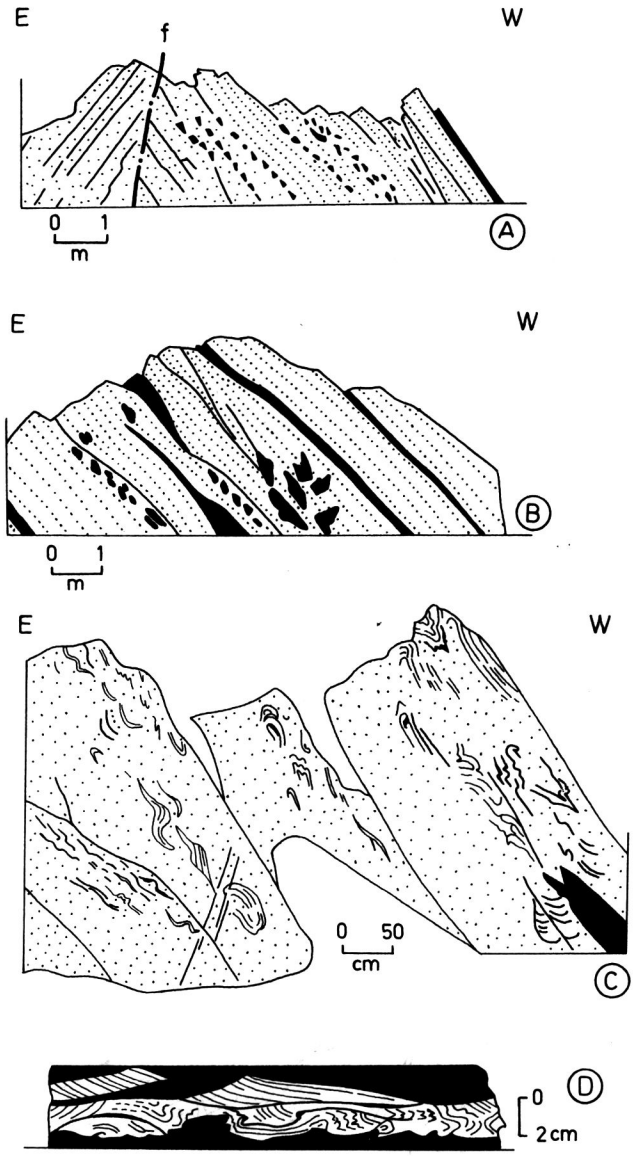

Fig. 2. Sedimentary features of the Hope Bay Formation, Trinity Peninsula Group, at Hope Bay. A, B — amalgamated homogenous sandstones with shale intercalations and clasts (in black), C — slumping visible in deformation of lamination and current ripples within amalgamated homogenous sandstones, D — asymmetric current ripples, load-casted in the lower part of figure

The age of the Hope Bay Formation is still under debate. According to Grikurov and Dibner (1968), based on sporomorphs obtained from shale intercalations, it corresponds to Early and Middle Carboniferous, a view criticized by Schopf (1973). Taking this into account, numerous samples

for sporomorph investigations were taken. Mega-plant remains have been collected at several sites, mainly in the upper part of the Hope Bay Formation at Scar Hills; some of them resemble those illustrated but not determined by Schopf (1973) from the Miers Bluff Formation on Livingston Island.

The Hope Bay Formation of the Hope Bay area lithologically resembles sediments of the Miers Bluff Formation on Hurd Peninsula (Livingston Island), moreover some parts of the Legoupil Formation at Cape Legoupil, and a lower part of the Trinity Peninsula Group at Paradise Harbour, Danco Coast (*see* Birkenmajer 1987; Birkenmajer and Doktor, *in press*). It is different from the upper part of the Trinity Peninsula Group at Paradise Harbour (*op. cit.*), and from fossiliferous Triassic part of the Legoupil Formation at Cape Legoupil (*cf.* Thomson 1975). New site with bivalve shells has been found by A. K. Tokarski on Gandara Island near Cape Legoupil, comparable with those described earlier by Halpern (1965) and Thomson (1975a, b).

(2) Mount Flora Formation

Terrestrial, fresh-water succession of coarse conglomerates with plant remains (lower member), followed by plant-bearing sandstone-conglomerate complex with shale intercalations (upper member), exposed at Mount Flora at Hope Bay, represents the Mount Flora Formation (Fig. 3).

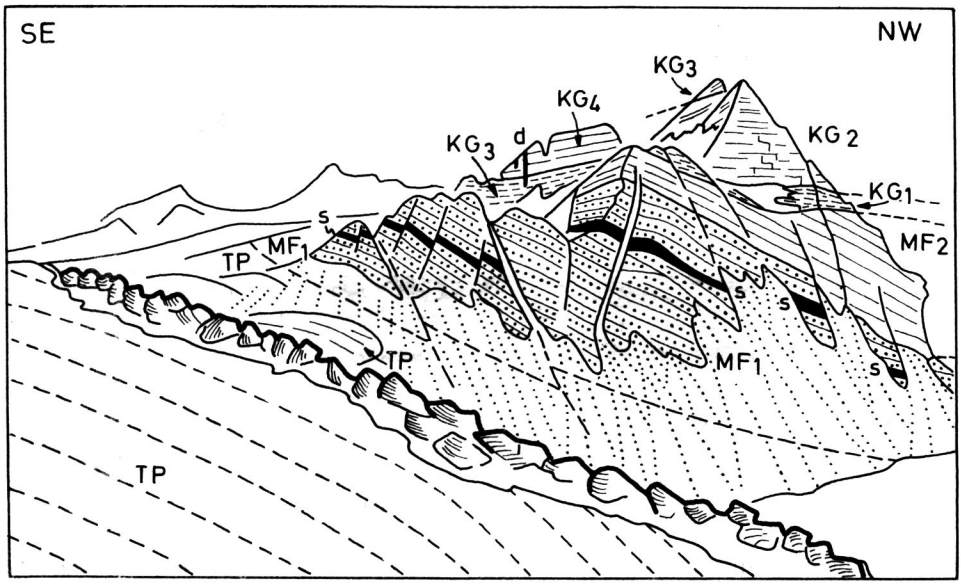

Fig. 3. Perspective view of Mount Flora, Hope Bay. TP — Trinity Peninsula Group (Hope Bay Formation), MF_1—MF_2 — Mount Flora Formation, lower and upper members, KG_1—KG_4 — Kenney Glacier Formation, successive members s — acidic sills, d — basic dykes

This formation rests with an angular unconformity upon folded and eroded Hope Bay Formation, as postulated already by Adie (1964) and Bibby (1966). This is well recognizable on different strike-and-dip patterns in both formations, however their contact is nowhere exposed well enough for detailed studies.

The age of the formation, as based on well preserved plant megafossils, was originally determined as Middle Jurassic (*see* Andersson 1906; Halle 1913). Late Jurassic or Early Cretaceous (Stipanicic and Bonetti 1970 — *fide* Thomson 1977, pp. 888—889; Thomson and Pankhurst 1983), and Middle-Late Jurassic ages (Rees 1988), have also been proposed. A large collection of plant megafossils was assembled (by K. Birkenmajer and W. Danowski) from both loose blocks and the rocks *in situ*.

(3) Kenney Glacier Formation

A complex of predominantly acidic (rhyolites, dacites) ignimbrites, lavas, tuffs and agglomerates, with subordinate chert beds and with fossilized wood fragments, distinguished as the Kenney Glacier Formation, unconformably covers plant-bearing strata of the Mount Flora Formation: the angle of unconformity amounts to 20° (Fig. 3). Four lithostratigraphic units of member rank have been distinguished within the Kenney Glacier Formation: three lower ones (KG_1-KG_3) being represented by stratiform lavas, agglomerates and tuffs, the upper one (KG_4) by large-scale cross-bedded agglomerates. This volcanic complex, of either Upper Jurassic (*cf.* Adie 1964) or Lower Cretaceous age, has been included to the Antarctic Peninsula Volcanic Group by British authors (*e.g.* Fleming and Thomson 1979), however it differs very much from the APVG complex of Graham Land which is represented mainly by stratiform basaltic-andesitic subductional complex (*cf.* Birkenmajer 1987). Samples for petrologic and radiometric investigations were taken.

(4) Andean plutons

Andean plutons have been mapped and sampled in the following areas: Hope Bay and Tabarin Peninsula (Trinity Peninsula); Arctowski Peninsula and Andvord Bay (Danco Coast, Graham Land); east coast of Anvers Island from Lion Island to Ryswyck Point, and Damoy Point on Wiencke Island (Palmer Archipelago); Melchior Archipelago (K. Birkenmajer with the help of W. Danowski and K. Rolnicki).

At Hope Bay and Tabarin Peninsula, gabbroic, dioritic and granitoid bodies cut through the Trinity Peninsula Group sediments often producing wide thermal aureoles in the latter.

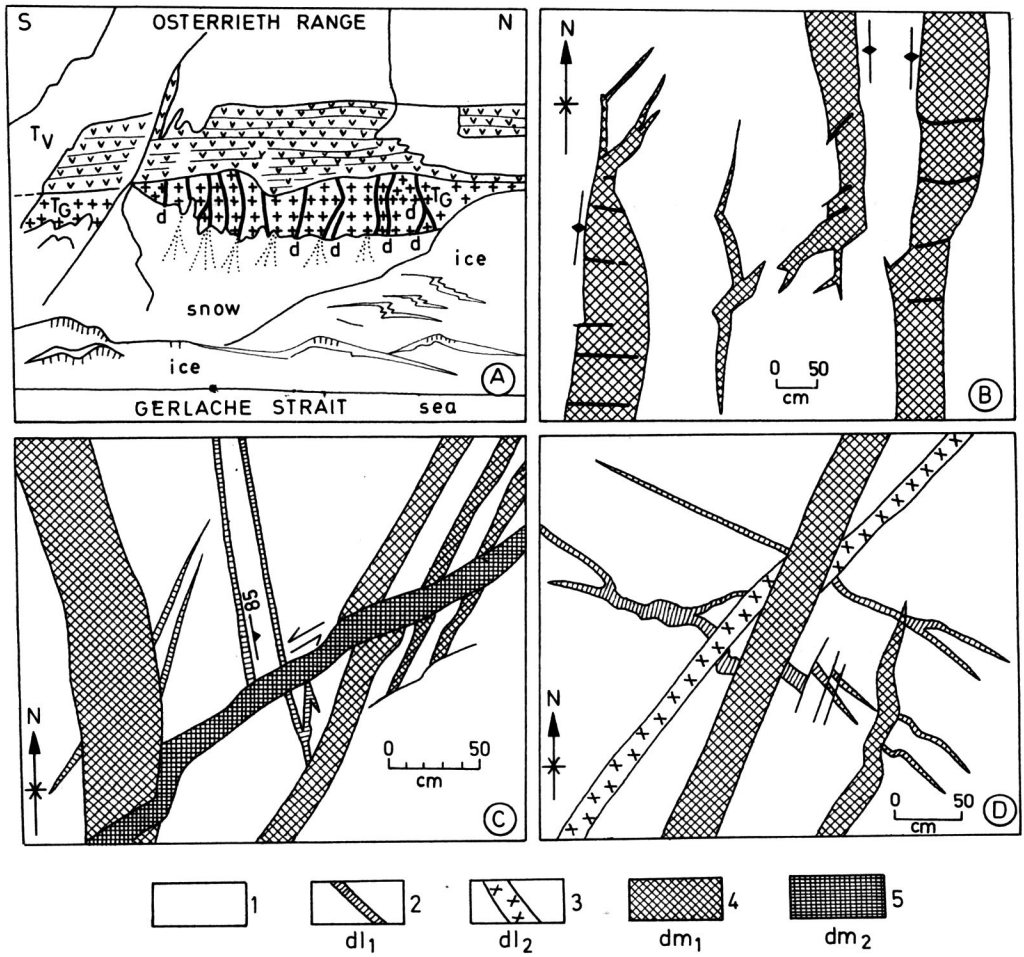

Fig. 4. Eastern coast of Anvers Island, between Lion Island and Dobrowolski Island. A — relation of Tertiary volcanic stratiform complex (T_V) to granitoid pluton (T_G) crossed by numerous dykes (d); note erosional unconformity between the lavas and the pluton, B—D — examples of dyke sets cutting through granitoid body: 1 — granitoid pluton, 2 — leucocratic veins of the first set (dl_1), 3 — leucocratic veins of the second set (dl_2), 4 — basic dykes of the first set (dm_1), 5 — basic dykes of the second set (dm_2)

At Arctowski Peninsula, the Andean plutons of granitic through tonalitic composition (*cf.* Fleming and Thomson 1979) represent mainly large sills concordant with gently folded complex of basaltic-andesitic APVG lavas and volcaniclastics. Roofs of these sills are well exposed and easily accessible at Orne Harbour and Selvick Cove, and below Sable Pinnacles (Arctowski Peninsula); they are well exposed but difficult to examine in vertical walls south of Sable Pinnacles, and at Rogné Island vis à vis Danco Island, moreover at Neko Harbour, Andvord Bay, and at Forbes Point (Andvord Bay). Exclusively of the last mentioned site where granitoid intrusion occurs

within the Trinity Peninsula Group sediments, all these sites are within the APVG complex.

It has been suggested, based on data from Paradise Harbour, south of Andvord Bay (Birkenmajer 1987), that granitoid sill intrusion during Mid-Cretaceous (a 96-Ma K-Ar date from Lemaire Island — *see* Fleming and Thomson 1979), post-dated slight tectonic deformation of the APVG complex dated there at about 117 Ma (Early Cretaceous). This suggestion seems to be valid also for the Arctowski Peninsula area, as indicated by a 114±11 Ma Rb-Sr date from the Neko Harbour granite, Andvord Bay, given by Pankhurst (1982).

Numerous sites have been visited by boat along the eastern coast of Anvers Island between Lion Island (northern entrance to Neumayer Channel) and Ryswyck Point (Schollaert Channel). A stratiform extrusive complex of Tertiary lavas, tuffs and agglomerates, well exposed in vertical walls of Osterrieth Range between Schollaert Channel and Mount Camber, rests here unconformably upon weathered and eroded granitoid pluton cut by numerous dykes (Fig. 4A-D). From a southern extension of this pluton, at Wiencke Island, have been reported Tertiary (Eocene) K-Ar whole-rock, mineral and Pb-α dates of 49—52 Ma (Fleming and Thomson 1979).

(5) Minor intrusions

Minor acidic and basic intrusions in form of sills and dykes have been studied and sampled especially at: Hope Bay; Cape Legoupil and vicinity; Arctowski Peninsula; eastern coasts of Anvers Island and Brabant Island; Hurd Peninsula, Livingston Island.

At Hope Bay, acidic sills and dykes cut through the Hope Bay Formation (Trinity Peninsula Group: ?Carboniferous) and the Mount Flora Formation (Jurassic — *see* Fig. 3), while basic dykes — through the Kenney Glacier Formation stratiform volcanics (Upper Jurassic or Lower Cretaceous?) and Andean plutons. The age of minor sills and dykes may correspond to Upper Cretaceous.

At Cape Legoupil (Antarctic Peninsula) and at Hurd Peninsula (Livingston Island), basic dykes cut through the Trinity Peninsula Group, the Legoupil Formation (Triassic), and the Miers Bluff Formation (?Carboniferous--Permian?), respectively.

At Anvers Island, several generations of basic and acidic dykes (*see* Fig. 4A-D) cut through granitoid pluton of probably Eocene age (see above), and evidently pre-date Tertiary stratiform volcanic complex of Osterrieth Range (?Neogene). Some dykes, striking SW-NE, are parallel to the NE-trending strike-slip Neumayer Fault (*cf.* Scott 1965; Fleming and Thomson 1979; Birkenmajer 1987), others may represent fills of tension gashes related to lateral translation along this fault, the rest may represent fills of conjugate

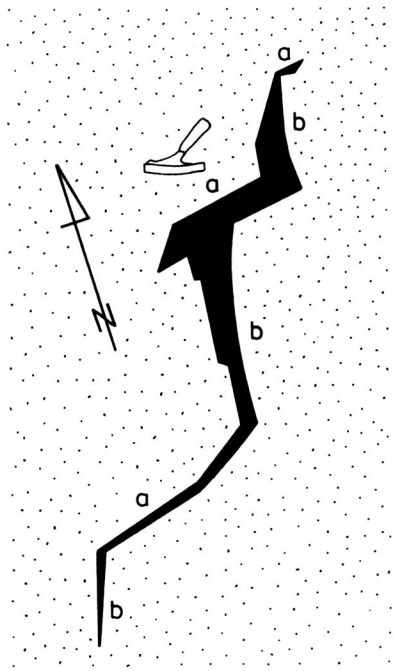

Fig. 5. Eastern coast of Anvers Island, Iceberg Point, basic dyke filling two sets of conjugate (?) shears in granite. a — N 60 W, b — N 10 E. Drawn from a photograph (by A. K. Tokarski)

shear joints (Figs. 4B-D, 5). Studies of small dykes have also been carried out on Brabant Island, east coast, and on Arctowski Peninsula (Orne Harbour, Selvick Cove, Neko Harbour); these dykes cut through the APVG complex and granitoid sills (*cf.* Birkenmajer, 1987).

(6) Tertiary glacially-controlled complexes

Supplementary investigations with additional sampling for radiometric and palaeontological dating (K. Birkenmajer, with the help of W. Danowski and K. Rolnicki) of glacially-controlled Tertiary deposits and associated volcanics (basaltic hyaloclastites and lavas, and basaltic-andesitic dykes), have been carried out on Magda Nunatak, Chopin Ridge, and at Lions Rump (Fig. 1: *10*), moreover in plant-bearing andesite lava and tuff complex at Mount Wawel (Fig. 1: *9*), King George Island.

(7) Deception Island volcano

Detailed field studies along with geological mapping were carried out on Deception Island (Fig. 1: *8*) to establish succession of lavas and pyroclastics of this active volcano. In the pre-caldera and post-caldera lithostratigraphic

groups (*cf.* Hawkes 1961; González-Ferrán and Katsui 1970; González-Ferrán, 1971), two new formations in the former, and six formations in the latter group have been distinguished.

Recent marine sediments

Recent marine sediments were studied by K. Görlich with the help of K. Rolnicki mainly in Hope Bay where a geological map of Recent fjord-bottom deposits has been prepared and source areas of suspension established. Sampling of bottom sediments and of suspension in water column was extended by K. Görlich to Paradise Harbour (Danco Coast) and Admiralty Bay (King George Island).

Tectonics

Tectonic structure of the Hope Bay area (Trinity Peninsula) and Gerlache Strait (between Brabant Island in the north and Wiencke Island in the south) was being studied mainly on mega-, partly also on meso-scale by K. Birkenmajer. In the latter area, the NE-trending Neumayer Fault (running along Neumayer Channel, northern part, and Peltier Channel — *see* Scott 1965; Fleming and Thomson 1979), which is a right-lateral strike-slip fault (Birkenmajer 1987), is displaced by E-trending right-lateral faults in the middle part of Wiencke Island and at the northern entrance to Neumayer Channel; it continues due NE along eastern coasts of Anvers Island and Brabant Island, in Gerlache Strait.

Mesostructural studies

Mesostructural studies have been carried out by A. K. Tokarski mainly in the Trinity Peninsula Group sediments, at Cape Legoupil and vicinity (Trinity Peninsula), and Hurd Peninsula (Livingston Island), partly also at Advord Bay (Danco Coast). According to his preliminary results, in the Cape Legoupil area, the sediments of the Legoupil Formation dip steeply at more than 35° due north, being metamorphosed into phyllites in the southern, and almost unmetamorphosed in the northern parts of the area. The rocks are folded around a N 75 E-oriented axis (Fig. 6) into a south-vergent anticline (in the south), followed by a syncline (in the north). Numerous minor folds with amplitudes ranging from a few mm to a few m occur in black shales and thin-bedded sandstones in the southern part,

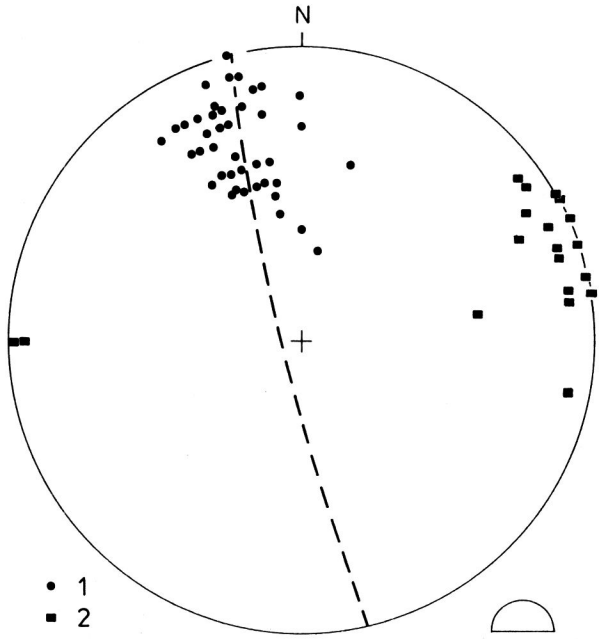

Fig. 6. Poles to bedding (1) and axes of minor folds (2) in sediments of the Legoupil Formation on Schmidt Peninsula (Cape Legoupil area), upper hemisphere plot, 60 measurements (by A.K. Tokarski)

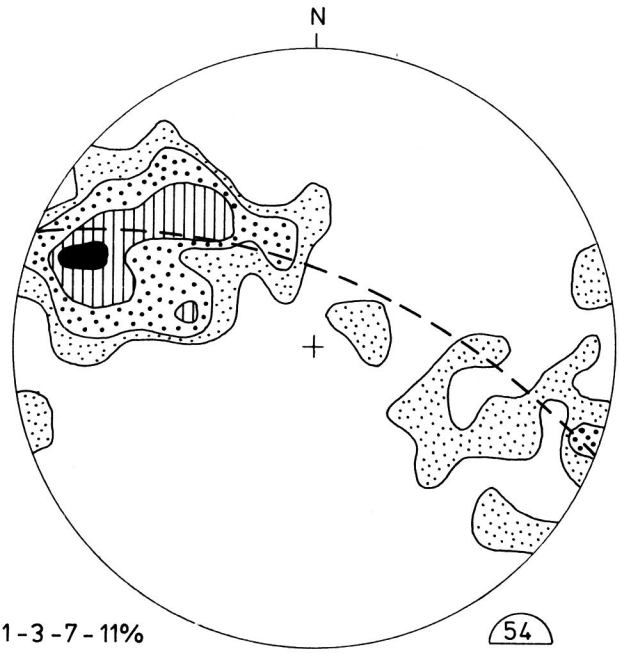

Fig. 7. Attitude of beds of the Miers Bluff Formation on Hurd Peninsula (Livingston Island), west from *Juan Carlos I* Station. Inset semicircle shows type of plot (by A. K. Tokarski)

with fold-axes being roughly parallel to major folds (Fig. 6). Such orientation of fold-axes differs from that reported earlier from the same area by Halpern (1965). The rocks of the Legoupil Formation are cut by numerous strike-slip faults directed N 10 W to N 50 W, and by basic dykes of two sets, directed ca N 35 E and ca N 65 E, respectively; in some places, these dykes pass into one another.

At Hurd Peninsula, A. K. Tokarski found sediments of the Miers Bluff Formation arranged in a recumbent east-vergent anticline (in the west), followed by a syncline (in the east), with subhorizontal axial surfaces. These folds are a result of deformation which proceded along an axis striking N 35 E and plunging 10° eastward (Fig. 7). Contrary to conclusions by Dalziel (1972), this trend is not parallel to the local trend in the South Shetland Islands or to that of the Antarctic Peninsula. Minor folds, averaging from a few to a few tens of cms, locally affect black shales exhibiting fold-axes parallel to those recognizable on mega-scale. The folded rocks are cut by strike-slip and normal faults representing several sets, and by basic dykes of two sets striking N 45 W (older) and N 70 E (younger), respectively.

Acknowledgements. The geological field group of the 3rd Geodynamic Expedition on M S *Jantar* is grateful to Professor A. Guterch, the leader of the expedition, and to Captain Zbigniew Kułaga, the master of expedition ship, and to his crew, for maintaining good working conditions and safe landing at numerous spots visited in the Antarctic Peninsula sector.

The commander and crew of the Chilean Base *O'Higgins* have provided excellent working conditions for Dr A. K. Tokarski and two geophysicists of our expedition. Their hospitality is here acknowledged wih gratitude.

While at Hope Bay, the geological group made use of an old British hut as good field headquarters, and was being helped with some logistic problems on land by the commander and crew of the Argentine Base *Esperanza*, and by Base doctor in case of a field accident. Last not least, good cooperation with the Spanish Base *Juan Carlos I* on Hurd Peninsula, Livingston Island, and with the Polish Base *Arctowski* on King George Island, is here acknowledged with pleasure.

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Received June 23, 1988
Revised and accepted July 1, 1988

Streszczenie

Badania geologiczne 3 Wyprawy Geodynamicznej Polskiej Akademii Nauk do Antarktyki Zachodniej, 1987—1988, prowadzone przy użyciu statku M/S *Jantar*, objęły następujące zagadnienia: studia sedymentologiczne i mezostrukturalne osadowej grupy Trinity Peninsula (?karbon — trias) w Hope Bay, na Cape Legoupil i w Anvord Bay na Półwyspie Antarktycznym oraz na Półwyspie Hurd (South Bay) na Wyspie Livingstona w Szetlandach Południowych; studia stratygraficzne i sedymentologiczne jurajskich osadów lądowych w Hope Bay (Półwysep Trinity); studia geologiczne i strukturalne w obrębie kompleksu lawowego bazaltowo-andezytowego Półwyspu Antarktycznego (dolna kreda), plutonów andyjskich oraz dajek kwaśnych i zasadowych (górna kreda i trzeciorzęd?) na Półwyspie Trinity i w rejonie Cieśniny Gerlache'a (Półwysep Arctowskiego, wyspy Brabant i Anvers); badania law i hialoklastytów bazaltowych występujących w obrębie trzeciorzędowych utworów glacigenicznych na Wyspie Króla Jerzego (Szetlandy Południowe); następstwo zjawisk wulkanicznych na Wyspie Deception (czynny wulkan).
Opracowanie wykonano w ramach CPBP 03.03.