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Geologic Significance of Regional Magnetic Anomalies in Coats Land and Western Dronning Maud Land

By Alexander V. Golynsky[1], Garrik E. Grikurov[1] and Eugene N. Kamenev[1]

Summary: Some aspects of the Late-Proterozoic-Early Mesozoic tectonic development of western Dronning Maud Land and Coats Land are examined in this study by using aeromagnetic data. Results of our study neither contradict nor support a postulated connection of the Kaapvaal-Zimbabwe Province into western Droning Maud Land but certainly indicate that the Coats Land crustal block has never been part of the African craton; it appears rather to be typical of the East Antarctic Shield. Our interpretation contradicts the suggestion that the Coast Land area is a continuation of the Mazatal-Yavapai-Grenville provinces of North America. Structural relationship of magnetic anomalies in the neighboring terranes (Maudheim Province, Shackleton Range and Coats Land) strongly indicate the existence of an ancient cratonic fragment in Coats Land. Magnetic anomalies related to the Ross orogenic event are very limited in western Dronning Maud Land and not discernible in the Shackleton Range area. This observation together with the geologic data allow us to suggest that a Ross-age suture resulting from Gondwana coalescence is not presented in western Dronning Maud and Coats Lands, apparently it must lie south of the current exposures of the Shackleton Range. Magnetic anomalies associated with fragmentation of Gondwana during the Mesozoic are depicted within the ancient Grunehogna cratonic fragment as isolated intrusions and either a linear chain of mafic intrusions or a deep-seated fault; apparently inherited some ancient inhomogenity in the Precambrian crust and are recognized within the Proterozoic mobile belt (the Maudheim Province) as intrusions of different composition which are predominantly alkalic in nature. Three well-known intrusions are located in the eastern shoulder of the Jurassic Jutulstraumen-Pencksökket failed rift whose axis is associated with negative magnetic anomalies, suggesting that axial intrusions not developed along the axis of the rift as a precursor to crustal splitting.

Zusammenfassung: Einige Aspekte der tektonischen Entwicklung vom westlichen Dronning Maud Land und Coats Land im späten Proterozoikum und frühen Mesozoikum werden mit Hilfe von flugmagnetischen Daten in dieser Studie untersucht. Die Ergebnisse unserer Studie stehen weder im Widerspruch noch unterstützend zu einer postulierten Verbindung zwischen der Kaapvaal-Zimbabwe-Provinz und dem westlichen Dronning Maud Land, aber zeigen deutlich, dass der Krustenblock von Coats Land niemals ein Bestandteil des afrikanischen Kratons gewesen ist; er erscheint eher typisch für den ostantarktischen Schild. Unsere Interpretation widerspricht dem Vorschlag, dass das Gebiet um Coats Land eine Fortsetzung der Mazatal-Yavapai-Grenville-Provinz von Nordamerika sei. Die strukturelle Beziehung zwischen den magnetischen Anomalien der benachbarten regionalen Einheiten (Maudheim-Provinz, Shackleton Range und Coats Land) deutet auf die Existenz eines alten kratonischen Fragments im Coats Land hin. Magnetfeldanomalien, die zur Ross-Orogenese in Verbindung stehen, sind für das westliche Dronning Maud Land sehr limitiert und für das Gebiet der Shackleton Range nicht identifizierbar. Diese Beobachtung in Kombination mit geologischen Daten erlaubt den Vorschlag, dass eine Sutur aus der Zeit der Ross-Orogenese, die aus der Formation von Gondwana resultiert, im westlichen Dronning Maud und Coats Land nicht existiert. Anscheinend liegt sie südlich des jetzigen aufgeschlossenen Shackleton Range. Die mit der Fragmentierung von Gondwana während des Mesozoikums assoziierten Magnetfeldanomalien sind innerhalb des alten kratonischen Fragments Grunehogna als isolierte Intrusionen, als lineare Kette mafischer Intrusionen oder als eine tiefliegende Verwerfung dargestellt. Scheinbar mit übertragen sind einige Inhomogenitäten in der Präkambrischen Kruste, die innerhalb des protero zoischen mobilen Gürtels (Maudheim- Provinz) als Intrusionen von unterschiedlicher Zusammensetzung, meistens alkalischer Natur, erkennbar sind. Drei gut bekannte Intrusionen liegen in der östlichen Schulter des jurassischen Jutulstraumen-Pencksökket "failed" Rift, dessen Achse mit der negativen magnetischen Anomalie assoziiert werden kann. Dies lässt vermuten, dass sich axiale Intrusionen nicht als Vorboten vom Krustenabbruch entlang der Rift-Achse entwickelten.

[1] VNIIOkeangeologia, 1, Angliysky Avenue, 190121, St. Petersburg, Russia

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INTRODUCTION

Coats Land (CL) and western Dronning Maud Land (WDML) are situated in the pivotal region which lay between East Gondwana and West Gondwana during the transition from amalgamation to Gondwana fragmentation. In the geodynamic context, this area has significant interest due to the recent proposal of the SWEAT hypothesis (Southwest United States-East Antarctica) which suggests that East Antarctica and Laurentia may have been connected in an Early Neoproterozoic supercontinent (MOORES 1991, DALZIEL 1991).

Many authors attempted to prove, improve or refuse a new hypothesis using geological and geophysical information (MOYES et al. 1993, 1994, STOREY et al. 1994). For example, geochronological, isotopic results and interpretation of Russian aeromagnetic data allowed STOREY et al. (1994) to confirm the existence of Grenvillian age rocks within both West and East Antarctica and support the juxtaposition of Antarctica and western North America in a Neoproterozoic supercontinent reconstruction. The location of the Grenville Front in Antarctica given by DALZIEL (1991; the area between Pensacola and Thiel Mountains was used as a piercing point) has been modified by them. According to MOYES et al. (1993), the Mid-Proterozoic to Late Cambrian tectonic history of WDML does not appear to reflect a period of major continental re-organization, but rather a less intense reactivation along the major features established during the preceding Kibaran (Grenvillian) orogeny at approx. 1100 Ma. They also concluded that the Pencksökket-Jutulstraumen divide does not represent a continuation of the Mazatal-Yavapai-Grenville boundary of North America, nor does it represent a Ross age suture resulting from Gondwana coalescence. Furthermore, GOSE et al. (1997) concluded that the East Antarctica and Laurentia poles of 1100 Ma do not coincide after restoration of the continents to a position suggested by the SWEAT hypothesis, based on new paleomagnetic determinations for granophyre and rhyolite rocks from the Littlewood and Bertrab Nunataks. This indicates either that the hypothesis is incorrect or that CL and parts of WDML were not part of the East Antarctic craton at 1100 Ma. In a new reconstruction given by GOSE et al. (1997), Coats Land and the Kalahari craton are placed within West Gondwana and off the present southeastern margin of Laurentia. At that time, TESSENSOHN (1997) noted that flat-lying, unmetamorphosed, felsic volcanics of the Littlewood Nunataks are not particularly good evidence for the presence of the Grenvillian fold belt in this area. In addition, recent geochemical results allowed DIVAKARA RAO (1996) to suggest that rhyolites and basalts of the bimodal volcanism represented in the Bertrab and Littlewood Nunataks have a common source of origin. The source magma, a melt of the

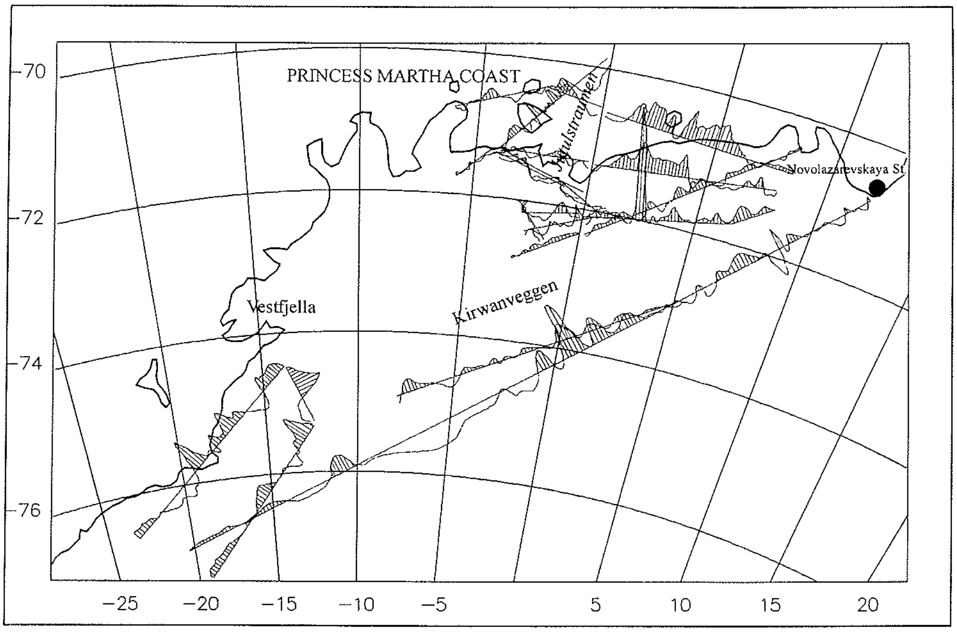

Fig. 1: Selected aeromagnetic profiles flown by the Polar Marine Research Expedition over western Dronning Maud Land (1 cm = 1000 nT).

Abb. 1: Ausgewählte flugmagnetische Profile, geflogen von der Polar Marine Research Expedition über das westliche Dronning Maud Land (1 cm = 1000 nT).

upper mantle appears to have evolved in a compressional tectonic regime and was intruded and extruded in an extensional rift tectonic setting.

In this paper we intend to further examine the relevant aeromagnetic data pertaining to the Late Proterozoic - Early Mesozoic tectonic development of WDML and Coats Land. Magnetic data have potential for resolving existing questions regarding the structural relations in this area.

BASEMENT GEOLOGIC PROVINCES

Several distinct geologic provinces were recognized in WDML and CL. The oldest of these is an Archean to Mid-Proterozoic cratonic fragment known as the Grunehogna Province (Groenewald et al. 1991). The Archean crust is characterized by the limited exposures at Annandagstoppane and immediately surrounding nunataks, where granite dominates (e.g. Ravich & Soloviev 1966, Knoper et al. 1995). This Archean crustal fragment is apparently overlain by the relatively undeformed and unmetamorphosed intracratonic-basin sediments of the Ritscherflya Supergroup (Wolmarans & Kent 1982). The sediments are intruded by tholeiitic sills and dykes of the Borgmassivet Intrusions. A recently determined U-Pb zircon age of 1135 Ma from felsic volcanic rock (Knoper et al. 1995) indicates deposition of the Ritscherflya Supergroup at the same time as the deformation at 1200-1000 Ma in the adjacent orogenic belt, the Maudheim Province (Groenewald et al. 1991). The highly-deformed orogenic belt extends longitudinally from the Weddell Sea depression northeastward through the Heimefrontfjella, Kirwanveggen, and H.U. Sverdrupfjella towards Gjelsvikfjella and Muhlig-Hofmannfjella (Groenewald 1993, Ohta et al. 1990). From the west, north and east the orogenic belt is juxtaposed against the Archean crustal fragment, at that time its southern boundary did not extend beyond the Shackleton Range as was suggested by Storey et al. (1994) and presumably juxtaposed against the unexposed East Antarctic craton.

The continuation of the Maudheim Province mobile belt to the west is only evidenced in the occurrence of coeval metamorphics in the Haag Nunataks area westward of the Weddell Sea Embayment. In this respect the rocks of the Touchdown Hills nunataks are of crucial importance. It is obvious, that comparison of the structural features of two neighboring terranes (Maudheim Province and Coats Land) is meaningless due to the great distance between them and due to existence on the CL side of only three tiny outcrops with total area less than 0.1 km^2. The predominant rock type at the Bertrab and Littlewood Nunataks is of granitic composition (Marsh & Thomson 1984). They describe the Bertrab Nunatak granitoid as a granophyre, which intruded by a dyke-like body of flow-banded rhyolite, and by a fine-grained dyke of altered microdiorite.

The Shackleton Range lies close to the proposed position of the Grenville front within Antarctica in reconstructions of Rodinia (Dalziel 1991, Storey et al. 1994). As was shown by Tessensohn et al. (1991), geological observations do not support this hypothesis. There are several tectonic models that can explain our knowledge about the present structure of the Shackleton Range and its relation to the Ross Orogen as the whole. Some of these models were considered by Kleinschmidt & Buggisch (1994) and they concluded that all of the models imply that the parts of Antarctica north of the Shackleton Range (WDML and CL, perhaps including the northwestern parts of the Shackleton Range itself) are more likely related to (Paleo-) Africa than to the East Antarctic Craton.

New isotopic characteristics of two infracrustal basement groups (Read and Stratton Groups) suggest a common protolith (Millar & Henjes-Kunst 1997). This argues against the existence of a pre-Ross oceanic basin between the northern and southern parts of the range. The supracrustal gneisses and metasedimentary rocks of the Pioneers Group that are tectonically interleaved with high-grade metamorphic basement rocks belonging to the Stratton Group have mid-Proterozoic (Grenvillian) Nd-model ages indicating a different type of crust more related to the Heimefrontfjella (Arndt et al. 1991, JACOBS et al. 1997). The zircon data also suggest that Grenvillian metamorphism affected Early Proterozoic Stratton Group gneisses of the northern Shackleton Range (MILLAR 1995). The situation is complicated by radiometric ages of unknown significance between 2300 and 2700 Ma obtained for emplaced granitoids from the Lagrange Nunataks and from the southern Haskard Highlands (PANKHURST et al. 1983), possible parts of the African Kaapvaal Craton or surrounding mobile belts as suggested BROMMER et al. (1997) or a more northern continent, microcontinent or terrane as considered by KLEINSCHMIDT & BUGGISCH (1994). The brief overview of the tectonic setting of the Shackleton Range shows that many problems have not really been solved at the moment, the kind of connections between the basement of the Read Mountains and the northern Shackleton Range, as well as with the CL crustal block remains unclear.

MAGNETIC ANOMALY IMPRINTS OF THE MAJOR TERRANES

The structural relationship between the WDML and CL terranes has remained uncertain due to a lack of information concerning sub-ice crustal structure. Russian regional aeromagnetic surveys of this area, completed as part of an integrated geophysical and geological investigation provide the opportunity to study the ice-covered territory where several Precambrian terranes are recognized.

The recently compiled aeromagnetic anomaly map of the Weddell Sea region allowed GOLYNSKY & ALESHKOVA (2000) within the study area to distinguish six distinct magnetic units attributed to different crustal terranes. It was shown that a magnetic low area occupied the Princess Martha Coast and linear short-wavelength magnetic anomalies over the Ahlmannryggen-Borgmassivet area correspond to the Archean to Mid-Proterozoic Grunehogna Province. A linear belt of magnetic highs and lows observed over H.U. Sverdrupfjella and Kirwanveggen is associated with the Middle to Late Proterozoic orogenic belt (Maudheim Province). The pattern of magnetic anomalies over the CL defines the extent of the CL crustal block and delineates structural elements and characteristic trends of the Shackleton and Argentine Ranges.

Correlative analysis of the magnetic field with the outcrop geology allowed the conclusion that the dominant source of anomalies is the Precambrian basement. Additional complexity of the magnetic fabric is caused due to the Mesozoic magmatism associated with the break-up of Gondwana and manifested in WDML as mafic volcanic rocks in Kirwanveggen (RAVICH & SOLOVIEV 1966, HARRIS et al. 1990), Heimefrontfjella (JUCKES 1972) and Vestfjella (HJELLE & WINSNES 1972), alkaline intrusions in Sverdrupfjella (RAVICH & SOLOVIEV 1966) and Kirwanveggen, and dolerite dykes (HARRIS et al. 1990) which intrude throughout the area. At Vestfjella basaltic flows are intruded by a 130 km^2 olivine gabbro, which is in turn intruded by dolerite dykes (HJELLE & WINSNES 1972, LUTTINEN et al. 1994). Sub-horizontal dolerite sills range in thickness from <1 m to >200 m and are exposed in the Theron Mountains, as well as at Whichaway Nunataks.

The magnetic anomalies associated with the Mesozoic magmatism are present in both the Grunehogna and Maudheim Provinces, as well as within the Coats Land crustal block and adjacent areas (GOLYNSKY & ALESHKOVA 2000). The overprinting character of magnetic anomalies is rather different within the study area, but we have not recognized any evidence in the onshore areas that fragmentation of Gondwana during the Mesozoic disregarded to full extent of older suture lines or boundaries between major provinces. One of the best examples of the Mesozoic influence on the basement anomaly pattern is observed in WDML. Here, the central part of the Grunehogna Province and northern continuation of the Maudheim Province is transected by the linear Princess Martha Coast Magnetic Anomaly (PMCMA) which can be interpreted as a linear chain of mafic intrusions or a deep-seated fault zone. Apparently, this anomaly may delineate a zone of structural weakness that initially developed during or prior the Gondwana separation. Several circular highs with amplitude up to 1700 nT occur within the Grunehogna Province supposedly caused by intrusions similar to those spatially attributed to the Maudheim Province and exposed in Utpostane and Muren (olivine gabbro) or near Straumsvola and Sistenup (syenite).

It is known that the Jurassic dolerite dykes from Vestfjella are strongly magnetized (2x10^{-3} emu.) relative to the basaltic lavas (5x10^{-5} emu.) and predominantly of normal polarity (KRISTOFFERSEN & AALERUD 1988, RUOTOISTENMÄKI & LENTIMÄKI 1997). Comparison of the regional magnetic anomaly map with the outcrop geology of Vestfjella shows that only the basalt flows near Plogen and Salryggen occur over a magnetic high; the others are associated with negative magnetic anomalies or lie along the flanks of highs. For this reason, it is difficult to infer the real extent of basalts or to correlate them with specific magnetic anomalies of regional extent. The causative source of the positive magnetic anomaly near Plogen and Salryggen is not clear, and it may be caused by infrastructural variations in the crust of the Maudheim Province mobile belt. However, coincidence of this anomaly with the gravity high (ALESHKOVA et al. 2000) indicates that it may be also associated with gabbro intrusion.

It should be noted that NE-SW-trending low-amplitude magnetic minima close to the major outcrops of the Vestfjella coincides with ice-surface lineaments and observed fracture trends such as the trends of the horsts, grabens and escarpments, implying major bedrock fault control. The older dolerite dykes known in Vestfjella (200-250 Ma) were intruded predominantly along the same trending fractures and may represent the initial period of rifting (JACOBS et al. 1996). Moreover, PETERS et al. (1991) pointed out that the conspicuous parallelism in strike between the Middle Jurassic dykes of Vestfjella and the Explora Escarpment, and between the Early Jurassic dykes in Ahlmannryggen and the Jutulstraumen-Pencksökket (J-P) graben, is a conclusive evidence for their mutual geodynamic formation.

Also of special note is the hinge zone magnetic lineament (HZL) clearly distinguished on magnetic images (see Figs. 1 through 5 in GOLYNSKY & ALESHKOVA 2000). Admittedly this lineament may represent a faulted boundary delineating major crustal extension along the continental margin of the southern Weddell Sea as a result of stretching and faulting during Jurassic/Cretaceous time and related to the initial rifting events of Gondwana. It is parallel to other outstanding magnetic features such as a wide linear belt of positive magnetic anomalies along the coast of WDML and CL including the Explora Anomaly and the Weddell Sea failed rift anomaly. Near the Princess Martha Coast the HZL transects the PMCMA and separates moderate-amplitude, long-wavelength anomalies to the north-west from moderate-to short-wavelength anomalies to the southeast. The increase in anomaly wavelength is due to a corresponding substantial increase in depth to Precambrian basement under the Weddell Sea shelf. The observed oval magnetic high of amplitude 350 nT immediately south of the HZL (74° 05' S and 19° 55' W) is coincided with the gravity anomaly (see Fig. 3 at ALESHKOVA et al. 2000) and supposedly may be interpreted due to igneous rocks such as olivine gabbro in Vestfjella. Farther southwest, over the CL shelf, several similar magnetic highs are located in vicinity of the mega-lineament. This implies that causative sources of the magnetic anomalies may be associated with an extensional episode along the Coats and western Dronning Maud Lands margin, whereas the HZL may be interpreted as deep-seated structure of regional scale that provided channel ways for the ascending magma during the Mesozoic time.

Large areas of Gondwana were affected by a major period of tectonism during the Late Proterozoic-Early Paleozoic, which culminated in a period of Late Neoproterozoic-Early Paleozoic deformation and/or magmatism termed the Ross or the Pan-African event (e.g. GROENEWALD 1993). The geological terranes of the study areas have had significantly different tectonic histories during the Ross orogeny. In western Dronning Maud Land, the cratonic Grunehogna Province appears to have remained stable since Grenvillian time, whereas the approx. 1100 Ma mobile belt was deformed during the Ross event although relatively gently when compared to the Shackleton Range or to the Transantarctic Mountains (MOYES et al. 1993). According to MOYES et al. (1993) the Ross event in WDML is characterized by pervasive mineralogical isotopic resetting, relative to open folding and thrusting towards the craton and limited magmatism, with only one large intrusion at Brattskarvet.

Examination of the aeromagnetic map covered the mountain areas of the WDML compiled by using 5 km flight-line spacing (see Fig. 7 in GOLYNSKY & ALESHKOVA 2000, this vol.) together with outcrop geology lead us to conclude that it yields important clues to the tectonic framework and the regional distribution of basement-rock types. For example, in the northern parts of the Heimefrontfjella, week narrow anomalies are not collinear with dominant trends of the Maudheim Province magnetic unit and apparently tend to reflect the Grenville-aged thrust/shear zones reactivated during the Ross orogeny (JACOBS 1991, JACOBS et al. 1997). Similar magnetic anomalies are discernible in the Kirwanveggen area and the nature of their sources is as yet unknown. At that time, the discrete high-frequency peak of around 500 nT amplitude occurred in vicinity of the thrust-related Brattskarvet intrusion of approx. 519 Ma and appear to be shifted northward, albeit after reducing to the pole the correspondence of a maximum to granitoids is improved. This high is located close to the Sverdrupfjella segment (GOLYNSKY & ALESHKOVA 2000) of the Sverdrupfjella-Kirwanveggen Anomaly as discussed below. We have not discovered any additional significant anomalies, which would be associated with the Ross-aged basement-rock types. The same is true also for the Shackleton Range where the Ross event was much greater than in the WDML (MOYES et al. 1993, TESSENSOHN 1997). These observations support the earlier conclusion of MOYES et al. (1993) that Gondwana amalgamation occurred along suture lines not currently exposed in outcrop in Dronning Maud Land. We acknowledge their suggestion that boundaries which would be consistent with the SWEAT hypothesis must either lie polewards, or the hypothesis is wrong.

GOLYNSKY & ALESHKOVA (2000) have suggested that the Maudheim Province magnetic unit corresponds to the highly deformed Mid- to Late Proterozoic orogenic belt which crops out in Heimefrontfjella, along the Kirwanveggen escarpment and in H.U. Sverdrupfjella. The major gneissic unit of the belt, the Sverdrupfjella Group, comprises various tonalitic, quartzofeldspathic and metapelitic gneisses with minor but extensive marbles and calc-silicate gneisses (GRANTHAM et al. 1988). Various intrusive units into these gneisses are present, and these suites were complexly deformed during a main event that has been correlated with the Kibaran or Grenvillian orogeny at approx. 1100-1000 Ma (BARTON & MOYES 1990).

The NS-trending magnetic anomalies of the northern part of the H.U. Sverdrupfjella segment of the SKA extend as far north as the border of the survey area. The causative sources of these anomalies are not obvious, and they may have been caused by infrastructural variations in the crust. At that time its central part corresponds to the Roerkulten granite of the orogenic event approx. 1100 Ma and located westward from the mountain range. Furthermore, GRANTHAM & HUNTER (1991) postulated that the spatial distribution of lithologies in the western and central H.U. Sverdrupfjella shows a lithological zonation with the various formations paralleling the boundary between the Ahlmannryggen cratonic terrane and the Sverdrupfjella terrane to the east. The lithologies closest to Ahlmannryggen include intermediate orthogneisses (the Gray Gneiss Complex of the Jutulrora Formation), which have the chemical characteristics of calc-alkaline volcanics, interlayered with banded paragneisses (the Banded Gneiss Complex). The sequence is interpreted as intercalated metavolcanics and arenitic to pelitic sediments (GRANTHAM & HUNTER 1991, GROENEWALD & GRANTHAM 1991), thus a possible interpretation is that the north-south trends may reflect the western extent of the Maudheim Province and magnetic anomalies are possibly caused by orthogneisses.

From these observations (structural grain of magnetic anomalies and known geology), the Sverdrupfjella segment of the SKA, that consists of three major anomaly segments along which different geologic processes have occurred, may delineate a zone of crustal weakness that initially developed during or prior to Kibaran/Grenville time. Subsequently, this part of mobile belt was deformed during the Ross event, albeit relatively gently when compared to the effects of the Kibaran orogeny (MOYES et al. 1993).

During the Jurassic time, this zone of weakness became active when the Jutulstraumen-Pencksökket thrust was reactivated in an extensional regime that led to intrusion of swarms of mafic and alkaline dykes and the intrusion of two plutonic alkaline and syenite complexes which are reflected by circular high-intensity magnetic anomalies (GOLYNSKY & ALESHKOVA 2000).

These are excellent examples illustrating that magmatic activity associated with the earlier stages of crustal thinning and magma underplating during the pre-rift stage appears to have a tendency to be alkalic in nature (BOTT 1979). Accordingly to ALLEN (1991), the Jutulstraumen-Pencksökket structure is a failed Jurassic rift, formed by reactivation of a pre-existing strike-slip fault forming the suture between the polydeformed high-grade terranes of H.U. Sverdrupfjella and Kirwanveggen, and the undeformed Grunehogna Province to the west. Several aeromagnetic intersections of the rift structure (Fig. 1) completed in the northern part of the rift show that its axis is mostly associated with negative anomalies. This is eventually showing that axial intrusions not developed along the axis of the rift as a precursor to crustal splitting.

We believe that the magnetic anomaly pattern observed in the CL area represents a mixture (jumble) of sources that vary in age as well as in size, depth and strike direction, possibly reflecting petrologic variations in more ancient basement (Archean?) that probably underlies the rocks of the granite-rhyolite terrane. Such inferences should be made with extreme caution, however, geological data strongly suggest the existence of another cratonic fragment to the south of the Maudheim Province mobile belt (MOYES et al. 1993). MOYES et al. (1993) mentioned that crystalline basement rocks of the Shackleton Range are suitable candidates for such a southern craton. Indirect evidence is also found in western Dronning Maud Land, since ARNDT et al. (1991) postulate such a cratonic presence in order to explain decreasing Nd values southwards in Heimefrontfjella. Other indirect evidence comes from East and West Antarctica. It is known that the greenschist facies metamorphic rocks of Archean age (Ruker Terrain) occupy the southern Prince Charles Mountains and southern parts of the Mawson Escarpment produce a magnetic pattern similar to that observed over CL (GOLYNSKY et al. 1995).

In our opinion it is hard to agree with the interpretation of the Coats Land magnetic anomaly pattern given by STOREY et al. (1994). It seems unlikely that the Grenvillian Front stretching from North America through the West Antarctica and towards WDML represents a single indivisible orogenic belt due to absolutely different magnetic signature over the Haag Nunataks and CL areas even if the last one admittedly has similarity with that observed across the Grenvillian Front in North America (HINZE & ZIETZ 1995). The observed structural pattern of the magnetic anomalies over CL and adjoining areas (WDML and Shackleton Range) do not allow us to support the suggestion that the Coast Land area is a continuation of the Mazatal-Yavapai-Grenville provinces of North America as was initially inferred by MOORES (1991) and DALZIEL (1991). Our arguments are based on the distinction of the magnetic anomaly pattern of the neighboring terranes which is remarkably visible on the magnetic anomaly map and other images (Figs. 1 through 5 at GOLYNSKY & ALESHKOVA 2000). The boundary between the Maudheim Province and CL terranes may be drawn rather distinctly along gradient zone of the westernmost positive magnetic anomaly of the Maudheim Province magnetic unit. Furthermore, the arcuate shape of two magnetic belts of the Shackleton Range bounded the CL crustal block from south and by the Druzhnaya Anomaly (GOLYNSKY & ALESHKOVA 2000) from the west suggests that these anomalies constitute a single tectonic zone that evolved as a marginal mobile belt of the ancient cratonic fragment located in CL. It should be noted that three aeromagnetic profiles flown in the south-eastern part of CL (Fig. 1) show remarkable similarities of the observed anomalies with those attributed to the Maudheim Province. It seems that they may swing towards the Shackleton Range and in this way outlining the extent of the CL crustal block as well as they may turn in the ice-covered interior of Antarctica. In any case, AWI aeromagnetic data coverage of the south-eastern part of CL (Jokat pers. comm.) could test these ideas.

We also suggest that magnetic anomalies of northern Berkner Island are also associated with this zone, but they are largely superimposed by N-S trends probably caused by Jurassic intrusions along the western border of the Filchner rift underlain by subsided and highly modified continental crust. Undoubtedly, it is difficult to be sure from the presented images (see Figs. 1 through 5, GOLYNSKY & ALESHKOVA 2000) that several W-E and NW-SE trending, subtle features recognized as a composite part of the Druzhnaya Anomaly, but not so obvious for northern part of the Berkner Anomaly (northward from 80° 20'S) constitute the northwestern continuation of the Shackleton magnetic unit. However, if true, this suggests that the structural trends of two belts of the Shackleton Range extend northwestwards beneath the sedimentary sequences of the Weddell Sea Embayment. The observed pattern of NW-SE and near W-E features invite speculation. Are they of different origin than the former original structures within the Precambrian and Early Paleozoic basement, the later Paleozoic intrusions during the Ross orogeny or fault zones subsequently reactivated in extension during pre-breakup phase? Or do they reflect volcanic rocks forming the Explora Wedge (HINZ & KRAUSE 1982, HINZ & KRISTOFFERSEN 1987) as suggested by HUNTER et al. (1996) or by integrated effect of the thick volcanic pile of Explora Wedge and the underlying intrusive dyke suite as considered by LEITCHENKOV et al. (1996)?

It was mentioned above that some magnetic anomalies over the northern part of Grunehogna Province are caused by mafic intrusions. The similar appearance of the magnetic anomalies of the Explora Anomaly in the eastern Weddell Sea area may be formed by similar intrusions. This is supported by observation of magnetic trends for the area between 30 °W and 20 °W which are in general discordance with the volcanic continental margin. It is difficult to agree with the suggestion that the Explora anomaly produced by integrated effect of volcanic layers and underlying dyke suite. It is known that magnetic properties of the Jurassic basalts from the Vestfjella are relatively low, whereas dolerite dykes are characterized by high levels of magnetic susceptibility (KRISTOFFERSEN & AALERUD 1988, RUOTOISTENMÄKI & LENTIMÄKI 1997). Other probable sources of NW-SE and W-E-trending magnetic anomalies which might be considered as component parts the Druzhnaya and Berkner anomalies, such as Paleozoic intrusions not known in vicinity of discussed area and must be excluded from consideration. Therefore it is reasonable to assume that these anomalies may be associated with the NW continuation of the Shackleton Range Proterozoic belts. At that time N-S-running residual magnetic anomalies along the eastern margin of the Berkner Island and the eastern component of the Druzhnaya Anomaly are apparently genetically associated with Jurassic intrusions similar to those exposed in the Dufek Massif and the Forrestal Range of the Pensacola Mountains (FORD & HIMMELBERG 1991).

There is no doubt that the magnetic anomalies of two units (Shackleton Range and Maudheim Province), reflected by high-grade metamorphic rocks have bounded character to the CL crustal block. Some questions in this respect immediately come to the mind, i.e. do they form one and the same magnetic unit representing an invisible mobile belt that is truncated on the Weddell Sea shelf by NE-SW-trending magnetic anomalies (Failed Rift Magnetic Anomaly)? Or do they turn in the opposite direction and may be outlined within the Gondwana assemblages? Such inference was made by CORNER et al. (1991) for the Dronning Maud Land anomalies (the Sverdrupfjella-Kirwanveggen Anomaly, in our interpretation) by correlation them with the Falklands Plateau anomalies and the Beattie magnetic anomaly which has a strike length of about 900 km and a maximum amplitude of 1050 nT in the east and occurred in the poly-metamorphic Namaqua-Natal belt, that rims the southern margin of the Kaapvaal craton of South Africa. The causative body of the Beattie Anomaly was found to have a depth of about 6 km. It was also suggested that it possibly is related to the Pan-African orogeny at circa 500 Ma (CORNER et al. 1991). The origin of the anomaly is rather speculative. CORNER (1989) proposed that the major anomaly in the Natal Metamorphic Province is genetically related to the Beattie Anomaly. It was also suggested that since the Natal Anomaly arises from craton-directed thrusts in a granite-gneiss terrane, a similar geological setting is possible for the Beattie Anomaly. This is in conflict with the interpretation of DE BEER & MEYER (1984) and JOHNSTON (1998) who favored mafic lithologies. For example, in accordance with the interpretation given by JOHNSTON (1998), the Beattie Anomaly extends through the length of the Karoo basin composed of a thick package of Carboniferous to Triassic detrital sedimentary rocks and may indicate the presence of a mafic intrusion coincident with the basin axis. It was suggested also that this dyke-like body probably intruded during the early stages of extension, and may have localized subsequent basin development. Although we find the hypothesis of CORNER et al. (1991) intriguing, the following observations are probably worth nothing.

The tectonic history of WDML during the Middle Proterozoic to Late Cambrian is very similar to southern Africa and does not appear to reflect a period of major re-organization in that area, but rather a less intense reactivation along the major features established during the preceding Kibaran orogeny at 1100 Ma (MOYES et al. 1993).

Magnetic anomaly pattern of two counterparts in Gondwana reconstruction is quite similar (Fig. 2), however there are some differences which do not allow us to accept Corner's interpretation. Correlation of the Beattie Anomaly of unknown origin with the Falklands Plateau anomalies related to unknown sources over the Falkland microplate margin and the western Dronning Maud Land magnetic anomalies associated with the Grenvillian age rocks of the Maudheim Province is to some degree subjective and incompatible idea, just for the sake of idea, to constrain the reconstruction of Gondwana by using the aeromagnetic and marine data. It is incomprehensible at all why two fragments of proposed Gondwanian magnetic belt (Beattie Anomaly and magnetic anomalies of the Falkland Plateau) originated possibly during Pan-African orogenic event as was assumed by CORNER et al. (1991) or even in the Mesozoic time were correlated with another one in Antarctica related with Grenvillian age rocks.

From our point of view it is incorrect to compare magnetic signature of two remote Gondwanian terranes without taking into account the data from the Mozambique plains and the continental margin of Africa. The same is true for the Mozambique Ridge which comprises a continental crust (MOUGENOT et al. 1991). Integration of all magnetic observations from the southern Africa continental margin with those over continent parts could shed light upon probable sources of the magnetic anomalies and could possibly be useful to constrain the reconstruction of Gondwana. At the moment it is unclear, what the relationship between magnetic anomalies in onshore and offshore areas is. Are they continued on the continent as in case of WDML or not?

Other aspect on which we are going to draw the attention is the obvious similarity between the Beattie Anomaly and the Princess Martha Coast Magnetic Anomaly (GOLYNSKY & ALESHKOVA 2000). Both of them are parallel to respective corresponding continental margins. At that time, the magnetic anomaly map published by CORNER & GROENEWALD (1991) (Fig. 2) exhibits a northwest-southeast-trending grain of short-wavelength magnetic anomalies consistent with the boundary between the Kaapvaal Province and the Namaqua Belt. This grain is clearly overprinted in the eastern part of Karoo Basin by the Beattie Anomaly and therefore it is reasonable to assume that it might be apparently associated with mafic intrusions injected into upper crust presumably during early Mesozoic rifting and magmatism affected both continental margins. This suggestion is also arguable, however at any rate magnetic anomalies associated with Jurassic volcanic sequences broadly developed along the eastern boundary of the Kaapvaal Province and within the Limpopo Province (CORNER & GROENEWALD 1991, HUNTER et al. 1991). The thick section of flood basalts (more than 10 km) within the Karoo Basin provides additional evidence that this region where the Beattie Anomaly is observed has a much longer and more complex history in comparison with WDML comprising remnants of Jurassic basaltic lavas of variable thickness but not exceeded 1000 m in Vestfjella.

The magnetic anomaly pattern observed over the north-eastern part of Kaapvaal craton in position suggested by CORNER & GROENEWALD (1991) is not compatible with the Grunehogna Province. More or less similar character of the magnetic anomalies within the Kaapvaal craton with those in Antarctica is recognized over the south-eastern part of the craton, i.e. in position proposed by HUNTER et al. (1991). In this reconstruction the most pronounced magnetic anomalies of both continents, the Beattie and DML Anomalies, also might form one indivisible magnetic belt whereas the Natal Anomalies and other linear magnetic anomalies within the Maudheim Province would have not any continuation into counterpart regions.

We strongly believe that an attempt to match two cratonic fragments by using similarity of their patterns when all data (aeromagnetic and marine) from the African part are not incorporated into the analysis, and when the full extent of the

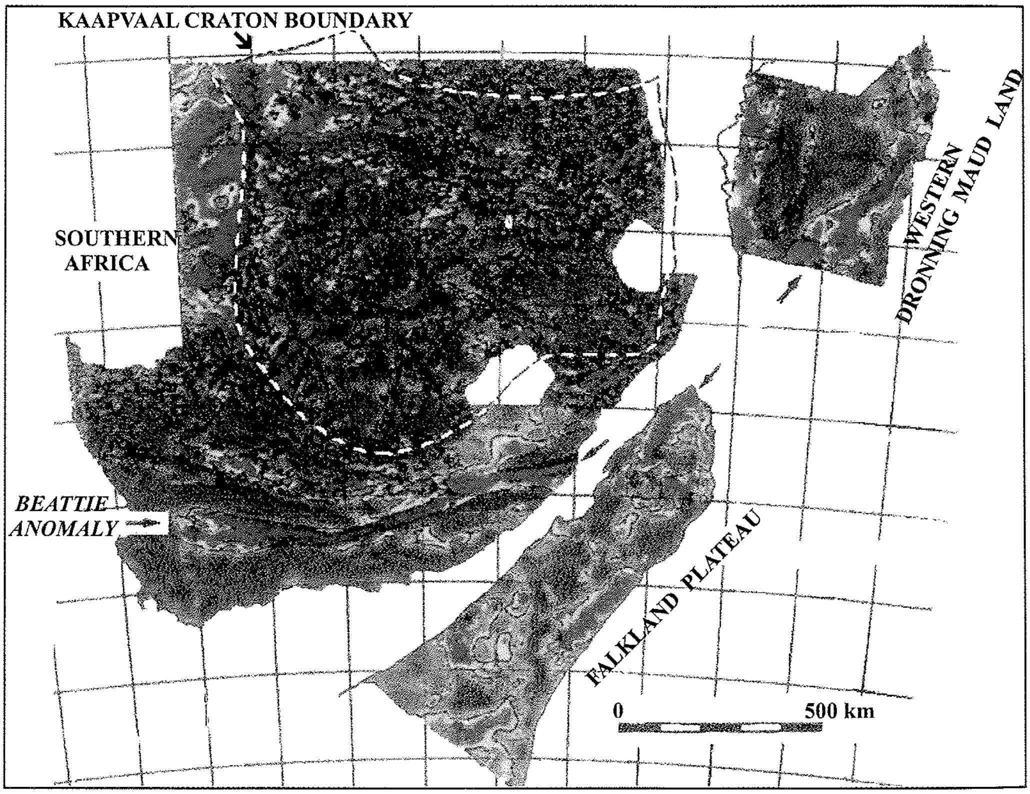

Fig. 2: Colour composite image of magnetic data covering southern Africa, the Falkland Plateau and western Dronning Maud Land based on CORNER & GROENEWALD (1991). The arrows point to interpreted extensions of the Beattie Anomaly into the Falkland Plateau and western Dronning Maud Land.

Abb. 2: Zusammengestellte Farbabbildung der magnetischen Daten, die das südliche Afrika und das westliche Dronning Maud Land abdecken, basierend auf CORNER & GROENEWALD (1991). Die Pfeile deuten auf die interpretierte Ausdehnung der Beattie-Anomalie in das Falkland Plateau und in das westliche Dronning Maud Land.

Sverdrupfjella-Kirwanveggen Anomaly is not known, will be subjective or speculative. It is also necessary to carefully analyze existent geophysical information derived by gravity and seismic investigations in both regions. The available seismic data show that the crust of the African Kaapvaal craton exhibits lower velocities than the crust in DML (HÜBSCHER et al. 1996). Two possibilities follow from these observations: either the Antarctic section of the Kaapvaal craton experienced a different or additional tectonic or magmatic influence relative to the African part, or the suggestion that the Kaapvaal craton continues into DML is incorrect. Despite there are some indicators that the Kaapvaal craton not continued into DML as was assumed by BARTON & MOYES (1990) who consider the Grunehogna Province to be a microplate unrelated to the Kaapvaal-Zimbabwe Province, HÜBSCHER et al. (1996) prefer the interpretation of lower crust affected by magmatism.

Undoubtedly, at this stage of investigations, when the AWI dataset from the south-eastern part of CL is not available for interpretation and comprehensive analysis and there is an essential gap in the aeromagnetic data coverage between H.U. Sverdrupfjella and the Sør-Rondane Mountains, any suggestions about continuity and correlation of the Maudheim Province magnetic anomalies with others either within Antarctica or counterparts of Gondwana assemblages will be speculative. This problem remains to be elucidated, but as stated above that arcuate fashion of two magnetic belts of the Shackleton Range bounded the CL crustal block from south and by Druzhnaya Anomaly from the west provides the opportunity supposedly to admit that these anomalies constitute single tectonic zone evolved as marginal mobile belt of the ancient cratonic fragment located in Coats Land. Therefore it is reasonable to assume that two magnetic units (Maudheim Province and Shackleton Range) might outline one and the same unit representing the Proterozoic mobile belt continuously stretching from WDML around the CL cratonic fragment towards the Shackleton Range. To a certain degree this is in agreement with the new geochronological data obtained for the Pioneers Group characterized by Grenvillian Nd-model ages (MILLAR & HENJES-KUNST 1997) indicating a different type of crust more related to the Heimefrontfjella (BROMMER et al. 1997).

CONCLUSIONS

Results of our study neither contradict nor support a postulated connection of the Kaapvaal-Zimbabwe Province into western Droning Maud Land but certainly indicate that the CL crustal block has never been part of the African craton. It appears instead to be typical of the East Antarctic shield. Bounding character of magnetic anomalies in the neighboring terranes (Maudheim Province and Shackleton Range) relative to the above mentioned crustal block strongly indicate the existence of an ancient cratonic fragment in Coats Land.

Our interpretation contradicts the suggestion that Coats Land area is a continuation of the Mazatal-Yavapai-Grenville provinces of North America due to the inconsistent structural pattern of magnetic anomalies within the proposed orogenic belt. Magnetic anomalies related to the Ross orogenic event are very limited in western Dronning Maud Land and not discernible in the Shackleton Range area. This, together with the geologic observations, allow to admit that Ross-age suture resulting from Gondwana coalescence is not presented in western Dronning Maud and Coats Lands. It must lie southwards of the current exposures of the Shackleton Range or at least in the Shackleton Range. The tectonic evolution of WDML from the Late Proterozoic to Cambrian time does not appear to reflect a period of major continental reorganization in that area, but a less reactivation along the structures arisen during the preceding Grenville orogeny at 1100 Ma.

Magnetic anomalies associated with the fragmentation of Gondwana during the Mesozoic are widespread and varied in form, size and length. The causative sources are predominantly igneous rocks. Structurally, they are depicted within the ancient Grunehogna cratonic fragment as isolated intrusions and linear chain of mafic intrusions or deep-seated fault (the PMCMA); apparently they inherited some ancient inhomogeneity in the Precambrian crust and are recognized within the Proterozoic mobile belt (the Maudheim Province) as intrusions of different composition but predominantly alkalic in nature. Three well-known intrusions are located in the eastern shoulder of the Jurassic Jutulstraumen-Pencksökket failed rift whose axis is associated with negative anomalies eventually suggesting that axial intrusions were not developed along the axis of the rift as a precursor to crustal splitting. Overprinting character of magnetic anomalies is rather different within the study area, but we have not recognized any evidences in the onshore areas that fragmentation of Gondwana during the Mesozoic disregarded to full extent older suture lines or boundaries between major provinces.

The origin of the source of many anomalies is obvious, where they correspond to known outcrop geology. Others relate to structures concealed under ice-cover and their origin is more speculative. However, in these cases the aeromagnetic data assist considerably in correlating known features and trends across large regions. We have attempted to suggest how some magnetic anomaly patterns can be interpreted in terms of the tectonic evolution and crustal development of WDML and CL. Further aeromagnetic investigations in particular over areas between the Sverdrupfjella Mountains in the west and the Sør-Rondane Mountains in the east as well over adjacent offshore areas up to Astrid Ridge and Queen Maud Ridge possibly underlain by continental crust would greatly increase the geological knowledge of the area.

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