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Further observations on Fe-Ti mines and prospects in the south Rogaland igneous province. Field report, 1996.

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REPORT

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Title:
Further observations on Fe-Ti mines and prospects in the south Rogaland igneous province.
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Summary:

The current report summarize the results of the 1996 field work in the south Rogaland igneous province regarding Fe-Ti deposits. Prospects and mines in the Sokndal area were visited and sampled in a continued effort to collect data on ilmenite occurrences in the Sokndal area (see also Schiellerup, 1996). In order to further establish the genetic implications of the Fe-Ti deposits in the anorthosite province additional mapping and sampling was undertaken in the target areas; the Storgangen layered dyke, the Mydland lobe, presumably part of the Bjerkreim-Sokndal intrusion, and the Bøstølen layered intrusion. Comments on the occurrences; Ymerstein, Vatland and Spjodevatnet have been included.

Keywords: Berggrunnsgeologi	Malmgeologi	Ilmenitt
Dypbergart	Anortositt	Fagrapport

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1 INTRODUCTION

The current report summarize the results of the 1996 field work in the South Rogaland igneous province which took place from June 19th to July 8th. Prospects and mines in the Sokndal area were visited/revisited and sampled in a continued effort to collect data on ilmenite occurrences in the Sokndal area. In addition a number of sulfide deposits in the area were sampled and studied as the overall occurrence of sulfide droplets in Fe-Ti rich cumulates implies that these may provide valuable information on the genesis of the oxide deposits in the province. These data is currently being processed and will appear in a separate report (Schiellerup, Larsen and Nilsson, in prep.). In order to further establish the genetic implications of the Fe-Ti deposits in the anorthosite province, additional mapping and sampling was undertaken in the target areas; the Storgangen layered dyke, the Mydland lobe, presumably part of the Bjerkreim-Sokndal intrusion, and the Bøstølen layered intrusion. Considerable field data and descriptions of general geology on these occurrences was reported by Schiellerup (1996). This work is considered part of the joint Norwegian geological survey-A/S Titania ilmenite program for south Rogaland, and a doctoral thesis at the Norwegian university of science and technology.

Trondheim, November 1996

2 FURTHER NOTES ON FE-TI OCCURRENCES IN THE EGERSUND AREA

2.1 THE MYDLAND LOBE

A brief survey of the Mydland lobe cumulates' potential as ilmenite resource was undertaken in 1995, and the general mineralogy and stratigraphy was presented along with a preliminary map in Schiellerup (1996). Preliminary data on petrography and mineral chemistry can be found in Karlsen et al. (1996) and McEnroe et al. (1996,) but so far the mineral chemistry as a function of stratigraphy has not been satisfactorily resolved.

A final map of the Mydland lobe is presented in Fig. 1. Further petrographical studies are needed to resolve the exact cumulate stratigraphy in the basal part of the intrusion. The lowermost cumulates in the layered series consist of a 450 m stratigraphic section of laminated and unlayered leuconorites. Sporadic blocks of anorthosite are present within the basal 200 m upon which a poorly defined narrow zone of higher Ca-poor pyroxene and oxide content seem to be developed neatly along strike. On top of the 450 m of leuconorites rests a 50 m wide xenolith-rich zone that can be followed along strike throughout most of the intrusion. The xenoliths consist of massive anorthosite and are up to tens of meters in diameter. Their presence are likely to reflect a larger stoping event in the evolution of the Mydland lobe magma chamber. The xenolith-rich zone roughly corresponds to the phase boundary where Ca-rich pyroxene and apatite joins the cumulate assemblage of plagioclase, Ca-poor pyroxene, ilmenite and magnetite. It also corresponds to a well defined zone of more mafic and banded norites displaying various kinds of impact related structures. Unlayered gabbronorites make up the bulk of the cumulate pile above the xenolith-rich zone but changes gradually into densely layered, oxide rich mafic gabbronorites and melagabbronorites. From 700 to 1000 m above the lowermost exposures a continuous 200-300 m wide band of oxide-rich melagabbronorites can be followed along strike throughout the intrusion (two km). Above approximately 800 m Ca-poor pyroxene is present as inverted pigeonite. Up sequence the melagabbronorites turn into laminated gabbronorites and the intensity of modal layering decrease. No distinction have been made between various types of mangerites and quartz-mangerites and they have been mapped basically through the characteristic texture dominated by porphyritic mesoperthite crystals. Along the southern and eastern contact of the Mydland lobe the mangeritic rocks tend to be massive in the innermost 50 m and distinctly foliated further away. Foliation is always oriented parallel to the intrusion contact.

The Mydland lobe is surrounded in part by a thin sheet of fine grained jotunite resembling the intrusive rocks of the Eia-Rekefjord system. Minor isolated occurrences of the fine grained jotunite can also be found in the central upper part of the stratigraphy and as small veinlets along the margins. The jotunite may contain angular blocks of foliated norite and cuts the modal layering at near-right angels in the western part of the lobe. It often contain ruptured xenoliths of quartzmangerite in the vicinity of the contact between these two units. The relation between the jotunite and the Mydland lobe cumulates is clearly intrusive. The somewhat peculiar position of the Mydland lobe, totally surrounded by rock types likely to post-date the main "norite" magmatism, may be achieved through the action of the Eia-Rekefjord system on a solid block of Bjerkreim-Sokndal type cumulates.

The central 300 m thick zone of oxide-rich layered gabbronorite and melagabbronorite is as previously mentioned (Schiellerup, 1996) the main prospect for ilmenite reserves in the Mydland lobe. The ilmenite content may locally be as high as 25% but on average total Ti-contents tend to lie between 5 and 10% (see Nilsson & Staw, in prep.). An extensive amount of chemical data from XMET measurements on the prospects of the Mydland lobe is currently being processed (Nilsson and Staw, in prep.) and further mineral chemical data will be produced in near future. Apart from the quantification and quality assessment of the Mydland lobe ilmenite resources a future target on the Mydland lobe will be to geochemically affirm the consanguinity of the Mydland and Sokndal lobes.

2.2 THE STORGANGEN INTRUSION

The general geology of the Storgangen dyke as well as the mineralogy and to some extent the mineral chemistry have previously been reported by Schiellerup (1996) and Karlsen et al. (1996). The Storgangen intrusion is a relatively thin layered norite dyke that probably originated as a sill-like body transformed into a sickle-shaped structure through the relative movement of the Åna-Sira anorthosite and the Bjerkreim-Sokndal layered intrusion. The cumulates typically contain 20-50% ilmenite, 5-20% magnetite, 20-40% Ca-poor pyroxene and 10-30% plagioclase as well as accessory apatite, biotite, green spinel, pyrite, chalcopyrite and pyrrhotite/pentlandite, with considerable variability due to modal layering. Phase layering is expressed by the addition of Ca-rich pyroxene to the cumulate assemblage below the hanging wall contact. Cryptic layering is observed in both plagioclase and Ca-poor pyroxene as well as in ilmenite.

An additional profile was sampled in the central part of the intrusion consisting of 15 samples collected throughout the stratigraphy. The profile may reveal lateral variations in the intrusion and will, along with the previous sampled profile, be submitted for analyses of platinum group elements. Currently a number of samples are being processed at the university of Bergen to establish the Rb-Sr and Sm-Nd isotope systematics of the Storgangen intrusion and powders are being prepared for REE analyses. The main scope of the detailed geochemical work is to establish the genetic relations between the Storgangen intrusion and the Åna-Sira anorthosite and substantiate the magma chamber processes involved in the formation of rich ilmenite ore.

A single profile was measured with XMET for Fe and Ti at 25-50 cm intervals through the entire stratigraphy to see if the Ti/Fe ratio was controlled by stratigraphy. The ratio as a function of stratigraphic height is presented in Fig. 2 along with the Ti and Fe contents. No significant relation can be resolved. However the measurement is valid only in case of truly unweathered exposures as weathering will raise the Fe/Ti ratio. Variable degrees of weathering therefore have a considerable effect on the signal to noise ratio. In fact the Fe/Ti ratio stays remarkably constant throughout the section with the major extremes representing measurements on weathered surface.

2.3 THE BØSTØLEN INTRUSION

A brief survey of the Bøstølen intrusion was initiated during the 1995 field season with the collection of a number of samples for petrographical and geochemical work. During the 1996 field season the intrusion was mapped (1:5000) for the potential presence of ilmenite prospects, contact relations and layering to resolve any kind of magma chamber processes involved in the formation of this, the oldest major intrusive in the Åna-Sira anorthosite. As the oldest major intrusive the Bøstølen layered intrusion may yield important information on the genesis of the massif anorthosite and the related rock units. A map is presented in Fig. 3.

A larger scale map including the Bøstølen intrusion has previously been published by Krause et al. (1985) and the petrography described through a detailed profile northwest of Laksedalsvatnet in Krause and Pedall (1980). The current study is focused at the understanding of the magma chamber processes and the intention was to map the lateral and vertical extent of phase layering and study the evolution of synmagmatic structures. However, it is possible in field to establish the presence of several olivine bearing zones within the layered sequence but the mapable lateral extent of these zones never exceeds a few tens of meters and are not confined to specific stratigraphic levels in the intrusion. Phase layering is thus like the modal layering and external contacts extremely irregular. The main rock type is a layered noritic cumulate interchanging in sections with leuconorite, anorthosite and dense layers of oxide-rich pyroxenites and troctolites. Further petrographic studies are needed and in progress to understand the systematics of layering and cumulate sequence within the intrusion. An isotopic study has also been undertaken and are in progress.

Layered rocks of the Bøstølen intrusion can be followed in a north-south direction for approximately 3 km with the modal layering in general oriented parallel with the external contacts. The stratigraphic thickness of the layered sequence is in the order of a few tens of meters but variable and increasing towards north where the strike of modal layering turns from north-south to an east-west direction. In places the petrological and textural contrast to the neighboring anorthosite massif is indistinct but there appears to be a large number of xenoliths derived from the anorthosite included in the intrusion. The Bøstølen intrusion is transected both by pegmatitic norite belonging to the Blåfjell-Måkevatn system and Egersund basalt dykes. In terms of ilmenite resources the prospects are minor. Oxide-rich pyroxenite modal layers are best developed in the southernmost part of the intrusion where sequences of isomodal layers up to 1 m thick may be traced laterally over 100-150 m. No prospects of any significant extent have been observed.

2.4 YMERSTEIN FE-TI DEPOSIT

Carlson (1945) mentions an occurrence of Fe-Ti ore on Ymerstenfjellet in the Håland-Helleren anorthosite. The site was revisited during the 1996 field season but is now heavily overgrown and despite intensive search the dyke to which the Fe-Ti occurrences should be related could not be located. In conclusion the Ymerstein deposit may be considered a minor prospect.

2.5 VATLAND FE-TI DEPOSIT

The Vatland oxide deposit is found in the Håland-Helleren anorthosite in the vicinity of Birkeland west of Rekefjord and may be described as a set of veins and dykes of ilmenitic or ilmenoanorthositic composition. The veins and dykes are from a few cm's to 1.5 m thick and have been mined at at least three sites over a distance of 200 m in a north-south direction. The dykes are either made up by massive oxide, dominantly ilmenite, or by euhedral plagioclase phenocrysts suspended in an oxide matrix. The susceptibility data implies that magnetite is a minor constituent and the occurrence seems to be very similar to the Florklev-Ålgård deposits in the Åna-Sira anorthosite (Schiellerup, 1996). The Florklev-Ålgård deposits present high concentrations of low-quality ilmenite due to the absence of cumulate magnetite (Karlsen et al., 1996). The area is heavily overgrown but the extent of the mineralization seems to be rather small. An examination of the mineral chemistry should determine the value of the occurrence as a possible prospect.

2.6 PRAMSKNUTEN FE-TI DEPOSIT

The Pramsknuten Fe-Ti deposit consists of a number of small concentrated oxide occurrences on the western bank of lake Spjodevatnet in the Håland-Helleren anorthosite. Small scale mining has taken place at several sites in the area. The occurrence is rather scattered but is atypical in that the massif oxide veins and dykes are surrounded by extensive alteration zones several meters wide, implying the activity of fluids in connection with the injection of the oxide-rich liquids. The massif oxide occurrences are fairly rich in pyrite and seem to contain some amount of apatite (nelsonite rock). The mineral assemblage and overall occurrence is different from deposits previously described and the Pramsknuten deposit should be investigated thoroughly. Susceptibility measurements indicate that magnetite is a very minor phase but as the deposit seems to be unique no conclusions regarding the ilmenite quality should be drawn solely based on field observations.

3 CONCLUSIONS AND FUTURE WORK

No significant prospects have been found or rediscovered during the 1996 field season. The extent of oxide-rich rocks in the Mydland lobe have been mapped and may in conjunction with geochemical, XMET and petrophysical data be used in a final evaluation of the Mydland lobe as an ilmenite resource. More geochemical data are being produced and considering the strong stratigraphic control on the mineral chemistry it will be possible to predict the ilmenite quality at any point in the intrusion to great precision once the work has been completed. The results are likely to be applicable in the Bjerkreim-Sokndal intrusion in general and it is of immediate interest to confirm the consanguinity of the Mydland and Sokndal lobes. Mineable resources may also be found in Bjerkreim-lobe of the Bjerkreim-Sokndal intrusion.

The Storgangen intrusion still contains vast amounts of accessible resources and detailed geochemical work may still be able to identify stratigraphically restricted zones of special interest. Detailed petrographical and geochemical work are in progress to fully understand this significant deposit.

The importance of the Bøstølen intrusion lies more in its potential as a key to the understanding of the evolution of the province and the genesis of Fe-Ti rich rocks than in its potential as an ilmenite resource. Mapping have revealed the presence of some amount of oxide-rich pyroxenites but the intrusions potential as a mineable resource must be considered minor. Further petrographical and geochemical studies involving isotope systematics are in progress on the Bøstølen intrusion.

Three known prospects in the Håland-Helleren anorthosite have been visited and sampled. Of these the Pramsknuten deposit is the most interesting with respect to both resource potential and genetic understanding. More detailed geochemical work is needed and in progress.

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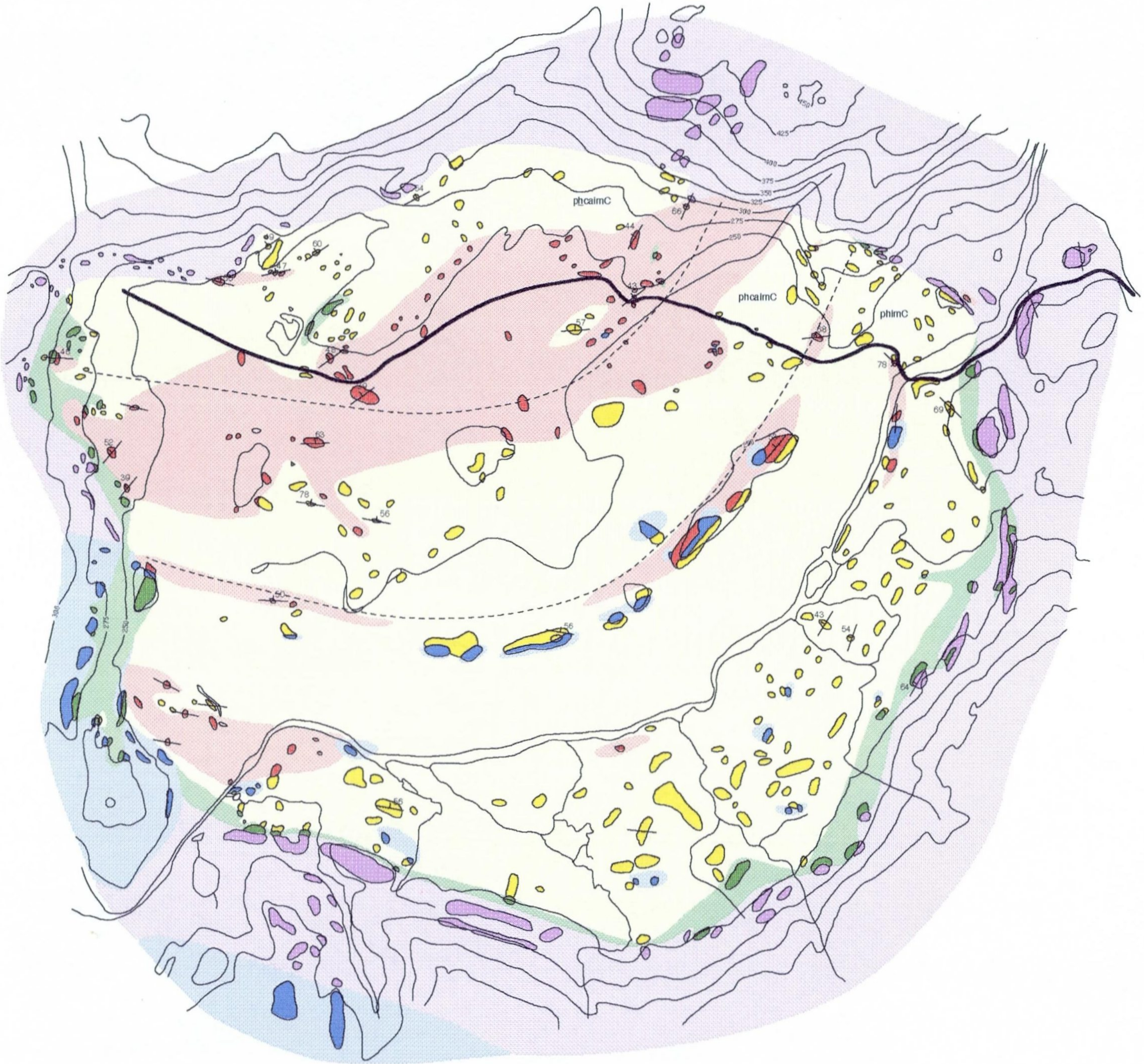
THE MYDLAND LOBE
South west Norway



- Massiv or foliated mangerite/quartz mangerite
- Fine grained jotunite
- Anorthosite
- Poorly layered or unlayered leuconorite/norite/gabbronorite
- Layered (mela-)norite/gabbronorite
- 69 Strike and dip of igneous layering

p	plagioclase
h	Ca-poor pyroxene
h̲	inverted pigeonite
c	Ca-rich pyroxene
a	apatite
i	ilmenite
m	magnetite
C	cumulate

Henrik Schiellerup, 1996

Storgangen XMET

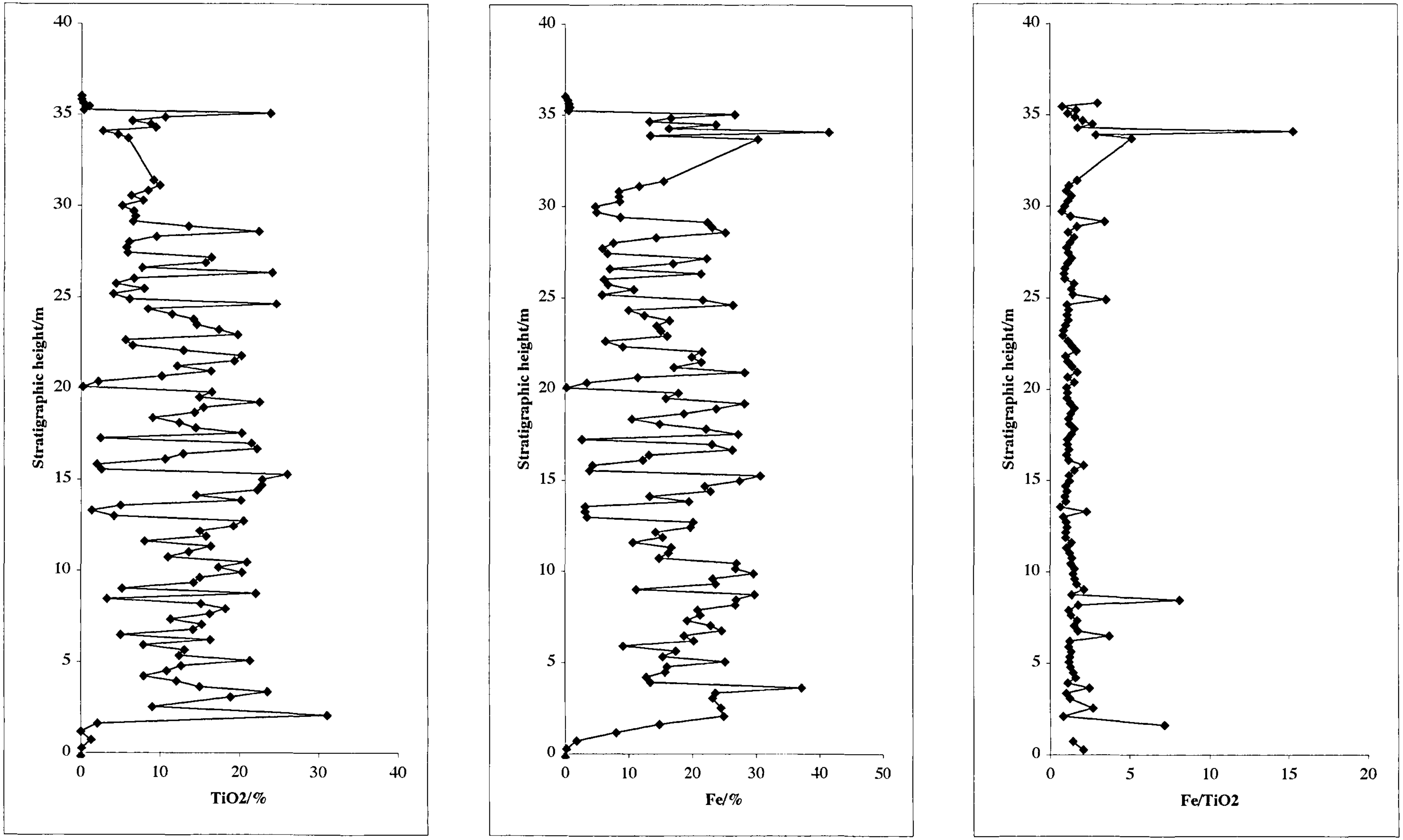


Fig. 2