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Geological correlation of the Pechenga and Pasvik zones

NORGES GEOLOGISKE UNDERSØKELSE

Postboks 3006 - Lade
7002 TRONDHEIM
Tlf. (07) 90 40 11
Telefax (07) 92 16 20

RAPPORT

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Forfatter: Melezhik, V., Nilsson, L.P. & Sturt, B.A.		Oppdragsgiver: Sulfidmalm A/S	
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As the result of an agreement between NGU and A/S Sulfidmalm, NGU has carried out geological investigations of the Pechenga and Petsamo Group rocks. The main purpose of these investigations was to provide a stratigraphic/tectonic correlation between the Pechenga Group rocks of the Nikel - Zapolyarny region and the equivalent Petsamo Group of the Pasvik valley.

The result of NGU's field investigations demonstrate that a detailed correlation of all significant horizons across the border-zone between Russia and Norway can be made. The results of this work also show the need for a number of significant revisions of the detailed stratigraphy of the Petsamo Group in both the Pasvik and Polmak areas.

The results of NGU's rock geochemical studies are presented in the report. A/S Sulfidmalm has previously received the analytical data for 220 samples. Recommendations are given concerning the potentially best Ni-Cu prospective areas.

Emneord:

bedrock geology/ore geology	geochemistry	stable isotopes
stratigraphic correlation	Ni-Cu ores	tectonics
lithology	radiometric ages	scientific report

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REPORT
ON THE FIELD WORK IS CARRIED OUT IN PASVIK AREA
IN JULY-AUGUST 1991

in accordance to the "Agreement for cooperative project, geological mapping of the Petsamo Group in Pasvik region, north Norway, between the Geological Survey of Norway (NGU) and A/S Sulphidmalm, Norway from 8 March 1991.

INTRODUCTION

The field work is carried out from 5th of July to 12th of August 1991 mainly in the Pasvik region and during three days in the Polmak area.

The field work program included number of positions:

- Mapping of the Petsamo and Pechenga Groups at the Norwegian-Russian border zone;
- Lithostratigraphical investigation of the Oksfjellet Formation;
- Mapping of the souther boundary of the Pasvik-Pechenga zones;

The main geological purpose was:

- Stratigraphical correlation Pasvik and Pechenga zones;
- Relationship between "Northern" and "Southern" Pasvik;
- Lithology and stratigraphy of the Oksfjellet Formation;
- Nature of boundary between Petsamo and Kobfoss Group.

The field work programme in 1991 was carried out by G.Juve,V.Melezhik, L.-P.Nilsson, D.M.Ramsay and B.A.Sturt.

MAIN RESULTS

The Pechenga Zone

General structure

The Pechenga zone is an asymmetric structure and can be divided into two subzones by the NW-SE trending deep probably synsedimentary Poritash Fault (Fig.1). The northern subzone is a monoclinal graben-synclinal structure dipping 20°-60° towards the south. The northern boundary of the north subzone has a primary stratigraphic nature. The southern subzone is characterized by intensely and heterogeneously deformed rocks dipping from 40-60° (both south and north) to vertical. The southern contact with Archean rocks is mainly tectonic one, probably an Early Proterozoic thrust.

The first deformation is represented by northward-verging thrusting, cleavage development, boudinage and north-verging asymmetrical folding with axial planes dipping to the south at 35° to 60°. Secondary deformation is characterized by open folding with steep northeast-trending axial planes.

Stratigraphy

The Pechenga zone is formed by Pechenga Group (northern subzone) and South Pechenga Group (southern subzone).

A remarkable feature of the Pechenga Group stratigraphy is the cyclic build-up of the sedimentary-volcanic formations. Each cycle begins with sedimentary and ends with volcanic deposition, further each cycle is separated from overlying by a nondepositional disconformity which generally is marked by palaeoweathering (Fig.2). The sedimentary and volcanic member of each cycle represent a sedimentary and volcanic formation. These formations, from oldest to youngest, are the sedimentary and volcanic Akhmalahti, Kuetsyarvi, Kolasyoki and Pil'guyarvi Formations (Fig.3).

The estimated total thickness of the Group is ca.10 000 to 12 000 meters. The volcanogenic component is about 80%.

The South Pechenga Group stratigraphy can only be described in a general manner because two different phenomena make a problem for the detailed subdivision of the Group. The first one is the coeval ultramafic and andesitic volcanism that is reflected as an interfingering relationship between andesitic and ultramafic volcanics and volcanoclastic sediments. The second problem of the stratigraphic subdivision is the tectonic imbrication present in this part of the zone. In general terms, the South Pechenga Group is younger than Pechenga Group. It comprises "black shales", synorogenic andesitic-picritic bimodal volcanics interbedded with volcanoclastic sediments and subordinate basalts, postorogenic andesitic volcanoclastic conglomerates, sandstones and siltstones (see attached geological map). In southmost part there are tholeiitic pillow basalts (Fig.1) that is compared with the Pil'guyarvi upper volcanics (see "Lithology and geochemistry"). The South Pechenga Group is over 6 000 meters thick.

Lithology and geochemistry

The Akhmalahti Sedimentary Formation comprises basal immature conlomerates in the lower and sub-aerial cross-bedded to horizontal-bedded gritstones and sandstones in the middle and upper parts of the unit.

The Akhmalahti Volcanic Formation is represented by sub-aerial amygdaloidal basalts, basaltic andesites and andesitic dacites (Fig.4) with comatiitic affinities (Predovsky et al., 1987). The REE pattern of the Akhmalahti Formation volcanics is characterized by slight enrichment in LREE (Fig.5).

The Kuetsyarvi Sedimentary Formation consists of alluvial current bedded and lacustrine synsedimentary folded quartzitic grit- to sandstones in the lower part (Quartzite Member) and red-coloured carbonate rocks, carbonate sandstones (dololithites) and stromatolitic and oncolithic carbonates at the top (Dolomite Member). Most carbonate rocks are protoevaporitic dolomites (Fig.6) extremely enriched by $\delta^{13}C_{carb}$ (Fig.7).

The Kuetsyarvi sediments are enriched by LREE (Fig.8) reflecting a source in continental crustal rocks.

The Kuetsyarvi Volcanic Formation rocks are mainly sub-aerial amygdaloidal trachybasalts, trachyandesites, mugearites and albitophyres in the lower part (Predovsky et al., 1974) that is separated by sub-aerial volcanoclastic thin conglomerate horizon from upper part of the Formation. The latter is represented by both alkaline and sub-alkaline basalts with subordinate mugearites. The lower and upper parts of the Formation are called respectively the Orshoayvi and Upper Basalt Members.

Most of the rocks of the Formation are alkaline volcanics (Fig.9). The rhyolites, andesites and dacites are enriched by magnetite and haematite and all of them are characterized by high magnetic properties.

The REE pattern of the Kuetsyarvi volcanics is similar to that for the Akhmalahti Volcanic Formation but some alkaline rocks are slightly enriched in HREE (Fig.10).

The Kolasyoki Sedimentary Formation is a typical "red bed" formation. The lower part of the Formation comprises alluvial fan deposits. They are current-bedded red-coloured arkosic grit- to sandstone. The middle part of the Formation is represented by lacustrine red-coloured arkosic haematite enriched coarse-grained gritstones and sandstones. The lower and middle part of the Formation is Red Bed Member. The upper part of the Formation (Dolomite Member) consists of protoevaporitic red-coloured carbonate rocks represented mainly by dolomites (Fig.6) intercalated with jaspers. Characteristic feature of these dolomites are their enrichment in Ba (up to 2%) and Mn (up to 2%). These dolomites are also distinguished by normal sedimentary isotopic record (Fig.7) from dolomites of the Kuetsyarvi Sedimentary Formation. The uppermost part of the Formation (Black Shale Member) is represented by carbon- and sulphur-bearing siltstones and basaltic tuffs.

The Kolasyoki Volcanic Formation is dominated by tholeiitic volcanics (Fig.11) occurring as pillow lavas, lava breccias, hyaloclastites and massive lavas (Predovsky et al., 1974). The Formation is divided by 50 to 100 meters thick "black shales" horizon into two equal parts. The "Black shale" unit is sulphide- and carbon-bearing thinly laminated fine-grained sandstones and siltstones alternated with basaltic tuffs, limestones (Fig.6) and microfossil-bearing cherts.

The REE pattern of the Kolasyoki volcanics is transitional to NMORB (Fig.12,13) (Kremenetsky, Ovchinnikov, 1986) but REE pattern for the "black shale" unit rocks (Fig.14) cannot be distinguished from Kuetsyarvi sediments and reflects same type of the continental crustal source.

The Pil'guyarvi Sedimentary Formation is the thickest sedimentary unit of the Pechenga Group and in places, it exceeds over 1 000 meters in thickness. The Formation comprises three members. The Lower Member (A) consists of carbon- and sulphide-bearing arkosic and greywacke sandstone and siltstone with subordinate polymict conglomerate lenses. The Middle Member (B) is represented by high carbon- and sulphide-bearing greywacke rhythmites interbedded with basaltic tuffs and diagenetic carbonate layers and lenses. Carbonate rocks are limestones with diagenetic records of $\delta^{13}C_{carb}$ (Fig.7). The Upper Member (C) of the Pil'guyarvi Sedimentary Formation is represented by ferropicritic tuffs and tuffits.

In two places, all three member of the Pil'guyarvi Sedimentary Formation are "eroded" by palaeoalluvial fans. Near the Kierdzhipori the alluvial channel is represented by phosphorus-bearing polymict fine-grained conglomerates, gritstones and sandstones. The next channel is the Lammas one that is distinguished by presence of large dimension granite boulders (up to 2 meters) in the greywacke and tuffitic matrix.

Recently there are discovered two eruptive centres of ferropicrires located within the Pil'guyarvi Sedimentary Formation. The position on the map of the eruptive centres and the description of the rocks belonged to the explosive facies are shown in Fig.15, 16).

The Pil'guyarvi Sedimentary Formation is penetrated concordantly by numerous differentiated gabbro-wehrlite intrusions containing economic Ni-Cu deposits.

The REE pattern for the siltstones of the Pil'guyarvi Sedimentary Formation (Fig.17) is similar to the Kuetsyarvi and Kolasyoki sediments and it reflects same type of the continental crust source.

The Pil'guyarvi Volcanic Formation is dominated by tholeiitic basalts with subordinate amount of ferropicrites and acidic volcanics (Fig.18) (Predovsky et al., 1974). The tholeiitic basalts occur as pillow lavas, lava breccias, massive lavas and tuffs. The ferropicrites are represented by massive, pillow and globular lavas. Some of the ferropicrites have spinifex structure (Suslova 1979). The acidic volcanics are mainly tuffs (Fig.19).

The REE patterns of the lower basalts are close to the NMORB type (Fig.20) (Kremenetsky, Ovchinnikov, 1886) while those of the basalts of the middle part are characterized by a slight enrichment in LREE (Fig.21), but the uppermost basalts are essentially enriched in LREE (Fig.22). On the base of the bulk composition the ferropicrites are comagmatic with differentiated gabbro-wehrlites (Predovsky et al., 1974). They have the comparable REE pattern (Fig.23-26) (Hanski, Smol'kin, 1989) and they are coeval within radiometrical analytical errors (Pushkarev et al., 1988; Hanski et al., 1990). The various lithological types of ferropicrites and the ferropicrites from both the Pil'guyarvi Sedimentary and from Volcanic Formations, all have similar REE patterns. The rocks display strongly negatively sloped chondrite-normalized REE patterns . The REE pattern of the acidic tuffs is similar to that of the ferropicrite type (Fig.27).

The South Pechenga Group rocks are presented by number of different associations which are described, from oldest to youngest, below.

The tholeiitic volcanics (southmost part of the Southern subzone on the Fig.1) occur as pillow and massive lavas with subordinate amygdaloidal lava flows and can be compared with the Pil'guyarvi upper volcanics on the base of the REE pattern resemblance (Fig.22 and 28).

The "black shales" of the South Pechenga Group are dominated by siltstone rhythmites with andesitic volcanoclastic matrix. The shales contain very often thin layers and lenses of carbon-bearing cherts.

The orogenic bimodal andesite-picrite association (Fig.29) is represented by andesitic massive lavas and tuffs, on one side, and by picritic pillow lavas, lava breccias and tuffs, on the other. The andesites are characterized by variations in MgO content and some of them are transitional to the high-MgO andesites and high-MgO basaltic andesites. Near the Poroyarvi Lake the andesites form a central type of palaeovolcano where they occur as andesitic lava breccias, volcanic agglomerates and tuffs. This bimodal volcanic association contains subordinate amount of volcanoclastic sedimentary deposits that are both andesitic and picritic in composition.

The REE patterns of the effusive andesites (Fig.30), subvolcanic andesites (Fig.31) and also of both andesites (Fig.31-31), high-MgO andesites (Fig.32) and high-MgO basaltic andesites (Fig.33) are comparable and have some resemblance with boninites.

The REE patterns of the picrites being coeval with andesites are different from latter (Fig.34,35). The picrites are distinguished depleted by LREE.

The postorogenic andesitic volcanoclastic sediments occur as unit containing the conglomerates beneath and sandstones and siltstones at the top. The pebbles from conglomerate have same REE pattern that the andesites have (Fig.31). Most pebbles bear clear evidence of pre-pebble tectono-metamorphic fabrics. This implies that subsequent to the formation of andesites and prior to the deposition of conglomerates and above underlying andesitic volcanoclasts an orogenic event occurred.

Radiometrical age

A lower age limit for the Pechenga Supergroup is placed by an Sm-Nd age of 2453±42 Ma for the General'skaya Gora intrusive (Bakushkin et al., 1990) which is overlain by basal conglomerates of the Akhmalahti Sedimentary Formation, and by an Rb-Sr age of 2330±38 for the Akhmalahti Volcanic Formation (Balashov et al., 1990) (Fig.36). The age of the latest deposition is problematic. There is a determination of 1778±45 Ma by Rb-Sr isotopic method for the Poritash subvolcanic andesites (Skuf'in, personal communication 1991) (Fig.36).Though without confirmation by U/Pb on magmatic zircons it is difficult to be sure of the significance of the result.

Geological position of the Ni-Cu bearing intrusions

Gabbro-wehrlite bodies containing economic Ni-Cu mineralization are spatially associated with the "black shales" of the Pil'guyarvi Sedimentary Formation ("Productive" Formation) (Fig.37). In the central part of the Pechenga Zone gabbro-wehrlites with sub-economic Ni-Cu sulphide mineralization also penetrate the Kolasyoki Volcanic Formation along the NW-SE trending Kolasyoki Fault (Fig.37). The main ore field, the eruptive centres of ferropicrites and spatial distribution of the ferropicritic flows within the Pil'guyarvi Volcanic Formation, are all apparently controlled by long-lived syndepositional faults (Fig.38).

There are known four main types of Ni-Cu ores in the Pechenga zone. Two of them are directly related to the gabbro-wehrlite bodies and third type can be deposited within fault zones not so far from the intrusions. These three types with short description are shown in Fig.39.

In 1989 Gorbunov with colleagues found a fourth type of the ore in Pechenga. They described globular ferropicritic flow with Ni-Cu massive sulphide ore beneath (Gorbunov et al., 1989). The thickness of the flow is ca. 12 meters including 3 meters of massive sulphides in the bottom. This ore-bearing flow is related to the eastern ferropicritic eruptive centre. Relatively recently Hanski has been discovered similar ferropicritic flow with massive sulphide ore body in the bottom (personal communication 1991) not so far from the western eruptive centre.

Preliminary sulphide isotope interpretation related to the problems of ore genesis

The sulphides of the "Productive" Formation belong to several generations. All the sulphides can be divided into sedimentary, early diagenetic, late diagenetic, catagenetic, metamorphic and hydrothermal. The $\delta^{34}S$ values of the sedimentary and early diagenetic sulphides collected from the rocks of the Member B vary from -8.3‰ to 12.4‰ (Tabl.). The average value is +0.4‰. Average figures of $\delta^{34}S$ for the late diagenetic and metamorphic sulphides of the Member B are +11.0‰ and 9.6‰ consequently. The spreading of the $\delta^{34}S$ values (from +2.1‰ to +23.8‰) and average figure $\delta^{34}S$ (+8.6‰) for both the early and late diagenetic sulphides of the Member C (mainly ferropicritic tuffs and tuffits) are rather similar (Table 1).

Grinenko and Smol'kin (1991) published sulphur isotope composition data for ferropicritic flows, ore-free and ore-bearing gabbro-wehrlite intrusions of the Pechenga Zone. They found that the ore-free ferropicritic flows within the Pil'guyarvi volcanics, ore-bearing globular ferropicriric flow at the top of the "Productive" Formation, and also The Kaula and Kotsel'vaara intrusions are characterized by $\delta^{34}S$ that is close to the meteoritic one. Four other massifs including both ore-free and ore-bearing ones are characterized by average figure of $\delta^{34}S$ that is +4‰. The ores of the Pil'guyarvi massif have +8‰ of the average value of $\delta^{34}S$ (Grinenko, Smol'kin, 1991).

Grinenko's interpretation is as follows: "There were two types of intermediate ferropicritic melt loci in the Pechenga zone. One type of locus producing the commercial ore intrusions was located in the Archean rocks but another one producing oreless intrusions was situated in the Proterozoic rocks".

It can be suggested another model of the ore forming processes if the sulphur isotope composition data are obtained for ultramafic flows, intrusions and their host rocks put together. First, the sulphur isotope composition of the sulphides of the sedimentary and early diagenetic stages is similar to the meteoritic standard and it reflects the same sulphur isotope composition as that of the basin water. It suggests that any lava flow having a mantle sulphur source could not change $\delta^{34}S$ even if it was contaminated by sulphur from water or nonconsolidated sediments because all of them have had a similar sulphur isotope composition. So it was in accordance with the data obtained by Grinenko. Second, the sulphur isotope composition of the sulphides of the late diagenetic stage (+9.6‰) is considerably different from meteoritic standard. In a case such as this, any intrusion penetrating those rocks could be contaminated by sulphur of the host and change the primary $\delta^{34}S$ value. This corresponds again to the real observation. But there is only one exception that is the Kaula-Kotsel'vaara deposit which is related to the intrusive body and in spite of this it has the $\delta^{34}S$ value being a meteoritic standard. In this case it should be also mentioned that the Kotsel'vaara-Kaula deposit is unusual one due to its position within the "Productive" Formation. The deposit sits the in uppermost level of the Formation and very close from ferropicritic tuff level (Member C) and from western ferropicritic eruptive centre.

A similar geological position is occupied by other ferropicritic flows with a massive type of ore that is described by Gorbunov and colleagues. In addition to this there is a new find of ferropicritic flow with massive sulphide ore by Hanski. This object is also located not so far from the Kaula-Kotsel'vaara deposit. Today there is no certain proof for either an intrusive or an effusive origin of the Kaula-Kotsel'vaara body. If this body represents an intrusion then there is an exception from our model and there is an unanswered question: why do the intrusion and the ores have meteoritic values of $\delta^{34}S$? If the body was a ferropicritic flow there would be a good agreement of geological and isotopic data with the proposed model. From prospecting point of view this means that in general there could be two different genetic types of the ores. One of them related to the differentiated gabbro-wehrlite intrusions that should occupy the lower and middle part of the "Productive" Formation. The other type is related to the ferropicritic flows and it should be located in uppermost part of the "Productive" Formation just between Member B and C.

The Pasvik Zone

General structure

In terms of geology the Pasvik zone is a one part of the Polmak-Pasvik-Pechenga-Imandra/Varzuga-Ust'Ponoy Greenstone Belt. The basement complex to the Petsamo Supergroup consists essentially of the Svanvik Gneiss. On the Norwegian side the Petsamo Supergroup rocks commence in the north at Brattli with the sediments of the Neverskrukk Formation. They together with overlying volcanics folded over the Svanvik Gneiss a broad antiformal arch, south of Svanvik, where they re-appear in the open synform of the Skogfoss Arch to the east of Hauge they pass over an open antiform and thence into Finland.

The Pasvik zone is an asymmetric structure. In the Oksfjell-Malbekk area the zone can be divided into northern and southern subzones. The boundary between subzones is a fault being the continuation of the Poritash Fault Zone (see attached map).

The northern subzone has a primary stratigraphic boundary and it is characterized by the monoclinal lying formations dipping 10°-60° towards the south. The southern subzone is dominated by intensely and heterogeneously deformed rocks dipping mainly towards the south. The contact of the southern subzone formation with Archean complex is an early Proterozoic thrust (see attached map).

Primary deformation of the Pasvik rocks is defined by a finely spaced schistosity which is axial planar to north-northeast and northwest verging asymmetrical folds (Hudson-Edwards et al., 1992). A second folding event produced open folds with limbs trending 45° and 165° and brittle-ductile shear zones with displacement ranging from a few to 250 meters.

Stratigraphy

The last descriptions of the Pasvik stratigraphy by Siedlecka with coauthors (1985) and Lieungh (1988, unpublished report) are based on the Lieungh's unpublished data. In accordance to Lieungh the Petsamo Group comprises five formation represented upwards by the Neverskrukk, Malbekken, Skogfoss, Oksfjellet and Krokvika Formations. New data obtained recently allow us to revise the previous stratigraphical scheme. The revised and mostly renamed stratigraphical divisions are described below.

The Pasvik zone is formed by Petsamo Supergroup divided into Pasvik (north subzone) and Langvannet (south subzone) Groups.

The Pasvik Group is characterized by the cyclic build-up of the sedimentary-volcanic formations and it comprises four sedimentary and four volcanic formations. These formations, from oldest to youngest, are the Neverskrukk, Båttjørna, Koievannet, Bergvannet, Skjelvannet, Stallvannet and Kiltjørnan Formations (Table 2). The supposed estimated total thickness of the Pasvik Group is from 500 to 4 000 meters. The volcanic rocks are about 80%.

The Langvannet Group stratigraphy is not clear though it can be described in general manner. This Group comprises a number of units that are represented by different types of rocks. From north towards south these units are as follows:

The "black shale" unit; picritic volcanic and volcanoclastic unit; andesitic volcanoclastic unit; sandstone unit.

The roughly estimated thickness of the Langvannet Group is over 1 500-2 000 meters.

The relationship between previous and new stratigraphical schemes is shown in Table 2.

Lithology and geochemistry

The Neverskrukk Formation consists of alluvial, alluvial fan and lacustrene conglomerates and sandstones and rest with primary unconformity and regolith on the rocks of the Bjørnevatn Formation. The conglomerates vary in facies southwards from polymict to monomict. The thickness of the Formation also varies considerably (Fig.40) resulting from the underlying palaeotopograpy.

The Båttjørna Formation is dominated by sub-aerial amygdaloidal sub-alkaline basaltic andesites and andesites (Fig.4). The lowermost part of the Formation locally is represented by volcanics with star-shaped glomerochrystic feldspar aggregates ("star-lava") (Lieungh, 1988). The uppermost part of the Formation contains of mainly amygdaloidal sub-alkaline dacites with subordinate picritic lapilli tuff (Fig. 4, sample 28) and with a number of the thin lenses of the volcanoclastic greywacke sandstones (sample 32). The REE patterns of the different petrocheochemical types of the volcanics including volcanoclasts are similar and they are characterized by enrichment in LREE (Fig.41), which is typical for sub-alkaline igneous rocks.

The Koievannet Formation consists of quartzitic and arkosic sandstones beneath and carbonate rocks at the top of the Formation. In accordance to the chemical composition the carbonate rocks are dominated by dolomites (Table 3). At the border zone, near the Skogfoss dam, there are observed current bedding and shallow-water ripple-marks in the terrigenous part of the Formation. It is related to the sub-aerial shallow-water environment of the deposition.

The Skogfoss Formation consists of different rock types. A number of analyses indicate a range in composition from ultramafic though to rhyolitic (Fig.9). There are both sub-alkaline and alkaline volcanics including such as alkaline basalts, havaiites, trachybasalts, trachyandesites, trachyrhyolites. The rhyolites, dacites and andesites are enriched by haematite and magnetite that provides a very high magnetic susceptibility of the rocks.

The lithology of the volcanics are different. The most rocks contain quartz amygdales. Acidic volcanics are dominated by thin lava-flows, ignimbrites, lava-breccias and thin-banded tuffs. The basic volcanics are mainly represented by thin lava-flows. The weathered flow tops are observed systematically indicating a sub-aerial environment of the volcanism.

The REE patterns of the acidic and basic rocks and also the sub-alkaline and alkaline rocks are similar. They are characterized by enricment in LREE and this is comparable with the Båttjørna REE patterns (Fig.42).

The Bergvannet Formation lies on the weathered crust of the Skogfoss volcanics. The Formation consists of red-coloured arkosic fine-pebble conglomerates, gritstones and sandstones beneath and Mn-rich carbonate rocks in the middle part pass upwards into carbonate-, carbon- and sulphide-bearing siltstones and basaltic tuffs.

The Skjelvannet Formation is very poorly investigated. It comprises monotonous tholeiitic massive and pillowed basalts with subordinate amount of the "black shales" that are represented as a number of discontinuously developed thin lenses in the middle part of the Formation.

The Stallvannet Formation comprises three members. The lower member rocks are represented by carbon- and sulphide-bearing quartz-rich sandstones and siltstones alternated with basaltic tuffs. The middle part of the Formation dominantly consists of carbon- and sulphide-rich siltstones with interbedded greywacke rhythmites. The siltstones contain centimetre-scale bands of pyrrhotite and diagenetic carbonate lenses. The upper member of the Formation, when present, consists of ferropicritic and basaltic tuffs (Hudson-Edwards et al., 1992).

The Kiltjørnan Formation is dominated by tholeiitic basalts with subordinate amount of ferropicrites and thin layer of the acidic volcanics. The tholeiitic basalts occur as pillow lavas, massive lavas and subordinate tuffs. The ferropicrites are represented by massive and pillow lavas. The acidic volcanics are tuffs. All volcanics belong to the sub-alkaline volcanic series (Fig.18).

The REE patterns of the basalts are distinguished different by enrichment in LREE from any MORB REE pattern (Fig.43).

The Langvannet Group rocks are described here according to preliminary stratigraphical divisions shown above:

The "black shale" unit is represented by carbon- and sulphide-rich rhythmicaly-bedded siltstones with an andesitic volcanoclastic matrix. The siltstones contain a number of thin chert lenses.

The picritic volcanic and volcanoclastic unit consists of a complex sedimentary-volcanic association that includes picritic pillow lavas, lava-breccias and massive lavas with interbedded picritic conglomerate and graded-bedded carbon-bearing sandstones, siltstones and mudstones (Table 4). This rock assemblage also contains some basaltic lava-flows. This association can be observed to alternate with andesites and andesitic volcanoclastic sediments. The petrogeochemical feature of the picrites, basalts and andesites is indicated in Fig.29.

The andesitic volcanoclastic unit commences with andesitic volcanoclastic schists containing andesitic volcanoclastic conglomerate lenses with andesite and iron-quartzite pebbles. The unit is dominated by andesitic volcanoclastic sediments with subordinate basalts, quartzites, cherts, carbonate rocks and carbon- and sulphide-rich schist.

The REE pattern of the basalt and picrite based on the single analyses is shown in Fig.44, 45.

Geological position of the ultramafic intrusions

Ultramafic bodies of a petrogeochemical gabbro-wehrlite equivalent are mainly located within the Stalvannet "black shales" and partly at the top of the Skjelvannet Formation.
The number of the intrusions positively corresponds with the thickness of the Stalvannet "black shales" and as a consequence
there is maximum of the ultramafic body abundance in the central Oksfjell area.

Correlation with the Pechenga zone

The Pasvik and Pechenga geology is demonstrated to have a considerable similarity in a number of aspects.
In general geological terms, the Pasvik and Pechenga Zones have a strong resemblance to each other. Both of them are asymmetrical structures clearly subdividing into northern and southern subzones (see attached map). There is an importance of distinguishing the northern subzone from the southern one because both of them contains "black shales" formations with various types of ultramafic rocks, but from the Russian experience only the one of the "black shale" formations, belonging to the Pechenga (or Pasvik) Group, is prospective for Ni.
The new stratigraphical division of the Pasvik Group demonstrates a strong correlation with the Pechenga Group. It is clearly shown that each sedimentary and volcanic formations including some delicate features (e.g. REE patterns, sedimentary and volcanic palaeoenvironments) follow from the Pechenga zone to the Pasvik (Tabl.2).
The "Productive Formation" of the Pasvik Zone is in general and in details also similar to that of the Pechenga Zone. Both of them comprise three members and contain carbon- and sulphide-rich sediments. The distinguishing features concern only to the lithology and grade of metamorphism. The Pasvik "productive unit" in the central part of the of the zone is enriched by basaltic volcanic components and it is metamorphosed higher P-T conditions. Also the grade of dynamic metamorphism is higher than that in the central part of the Pechenga zone.
The main "ore-field" of the Pechenga Zone is characterized by the three essential features: 1 - the highest thickness of the "Productive Formation"; 2 - the highest abundance of the ferropicritic lava-flows within the Pil'guyarvi Volcanic Formations; 3 - the highest abundance of the acidic tuffs. After discovering ultramafic flows and acidic tuffs in the Kiltjørnan Formation at Oksfjell there is demonstrated considerable similarity between internal build-up of the central part of the Pasvik and the so-called "ore-field" of the Pechenga (Fig.46).

CONCLUSIONS AND RECOMMENDATIONS

The geological investigations carried out in summer 1991 in the Pechenga and Pasvik Zones has shown an essential resemblance of these areas. From the comparison it is certain that the Pasvik Zone represents the so-called small-scale

Pechenga model.So from this study the Pasvik Zone is potentially prospective for Ni-Cu sulphide deposits related to the gabbro-wehrlite (or ferropicrite) magmatic complex.

From the Pechenga-Pasvik comparison the indications are that it is, perhaps, only the central part, of the area occupied by the Stallvannet and Kiltjørnan Formations, in Pasvik, spreading from Skjellvatnet, in the east (UTM 599) to UTM 591, in the west which represent a potentially interesting target area from a prospecting point of view.There is to be expected that within this target area two types of deposit may occur. The first type relating to the gabbro-wehrlite intrusions whereas the latter can be located anywhere within "black shales" of the "Productive Formation". The second type is probably connected with ferropicritic lava-flows that in accordance with the present-day knowledge of the Pechenga should be located at the top of the"Productive Formation". The degree of metamorphism is more strongly expressed in the Pasvik area so this has a most important consequence for the Pasvik Ni-Cu exploration, both at synclinal hinges of the first generation of the asymmetrical folds (Fig.39, Pil'guyarvi model) and in the pressure shadows (Kotsel'vaara model) of ultramafic bodies (Hudson-Edwards et al., 1992).

As we have, as yet, not had free access to geophysical or geochemical data acquired by A/S Sulfidmalm during 1991/92 our conclusions and recommendations have had to be based solely on our own fieldwork and examination of existing drill-core material (at Løkken).

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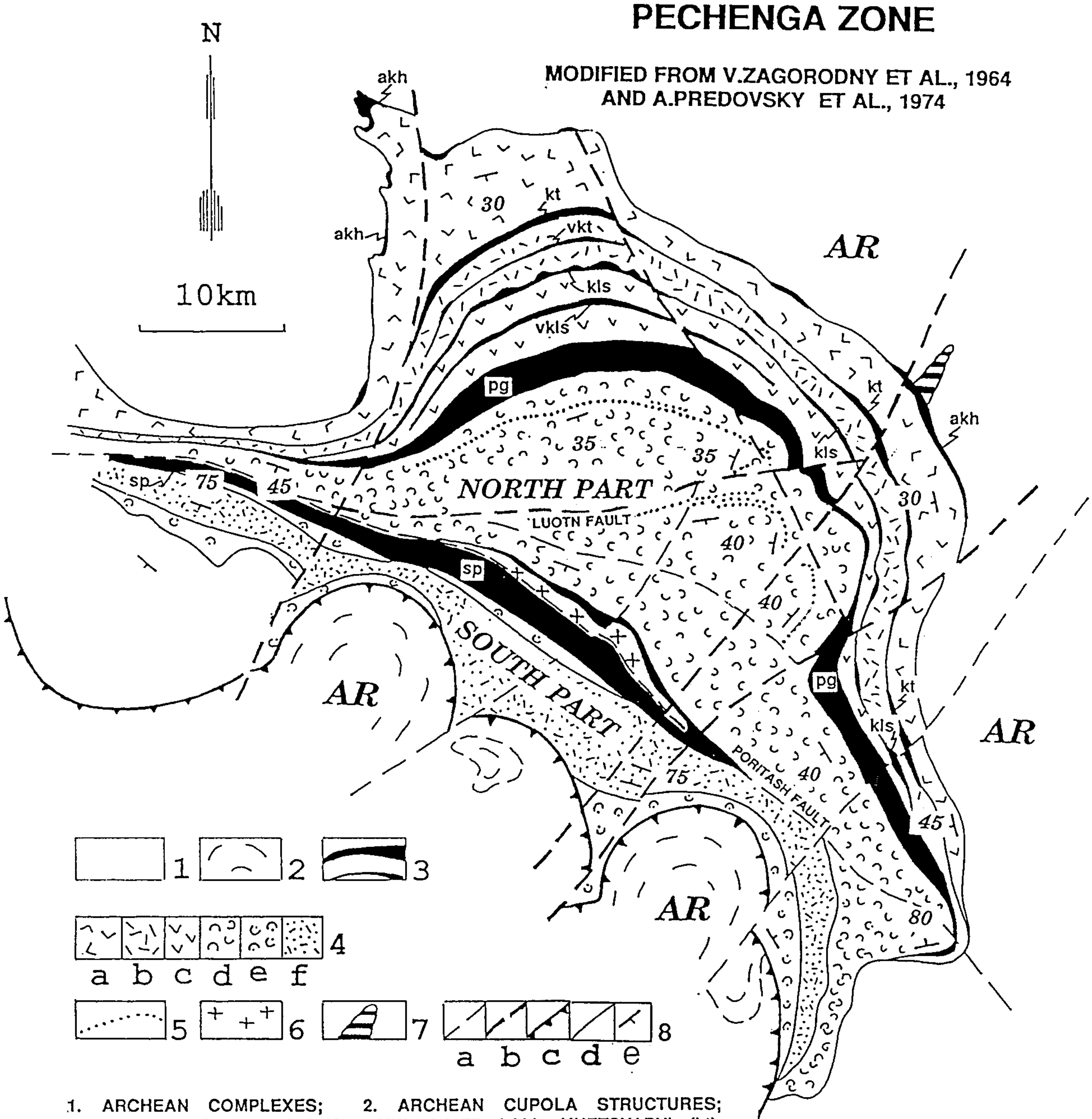
Fig.1

GEOLOGICAL SKETCH MAP OF THE PECHENGA ZONE

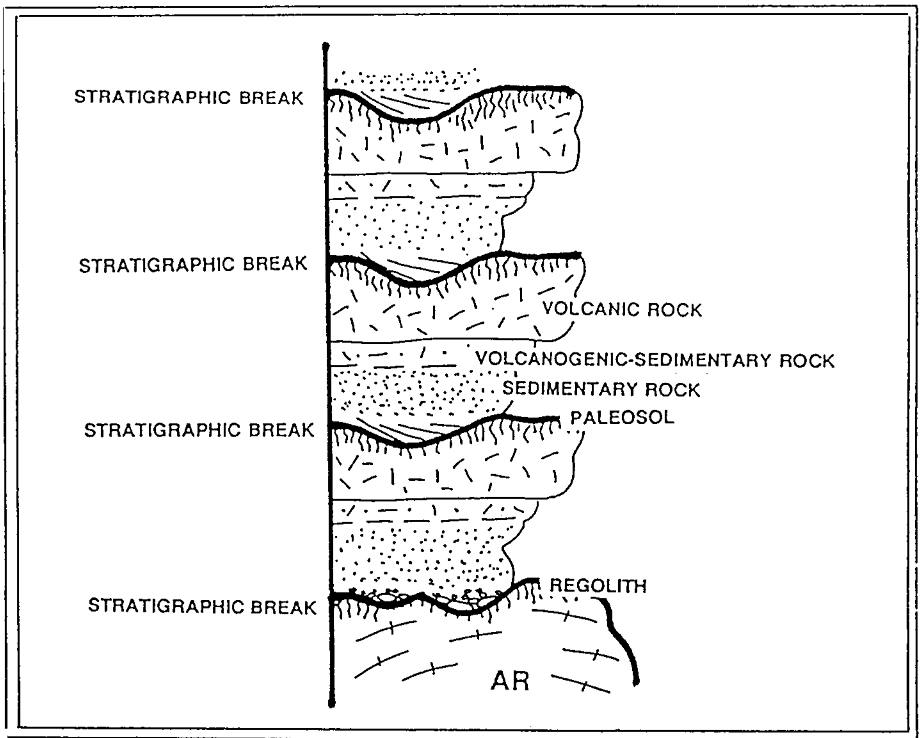
MODIFIED FROM V.ZAGORODNY ET AL., 1964
AND A.PREDOVSKY ET AL., 1974

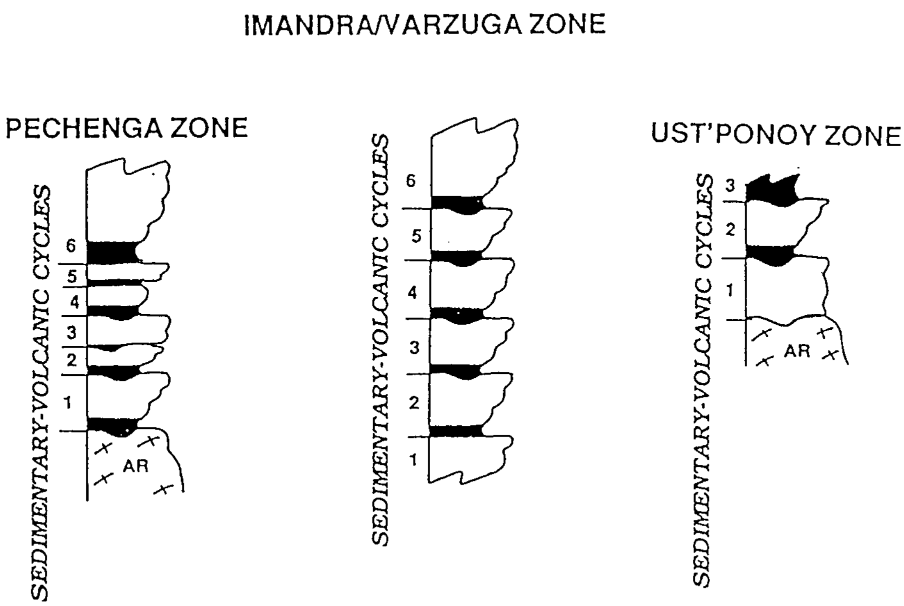


1. ARCHEAN COMPLEXES; 2. ARCHEAN CUPOLA STRUCTURES; 3.SEDIMENTARY FORMATIONS: AKHMALAHTI (akh), KUETSYARVI (kt), KOLASYOKI (kls), PIL'GUYARVI (pg), SEDIMENTARY HORIZONS WITHIN THE KUETSYARVI VOLCANIC FORMATION (vkt) AND WITHIN THE KOLASYOKI VOLCANIC FORMATION (vkls), "BLACK SHALE" FORMATION OF THE SOUTH PECHENGA GROUP (sp); 4. VOLCANIC FORMATION: AKHMALAHTI (a), KUETSYARVI (b), KOLASYOKI (c), PIL'GUYARVI (d), BASALT PILLOW LAVA OF THE SOUTHERN PECHENGA GROUP (e), ANDESITE-PICRITE BIMODAL VOLCANIC FORMATION OF THE SOUTHERN PECHENGA GROUP (f);
5. RHYOLITIC LAVA AND TUFF HORIZON; 6. ANDESITIC SUBVOLCANIC BODY;
7. EARLY PROTEROZOIC ULTRAMAFIC LAYERED INTRUSION;
8. POSTDEPOSITIONAL FAULTS (a), DEPOSITIONAL FAULTS (b), TRUST BOUNDARY (c), NORMAL STRATIGRAPHIC CONTACT (d), STRIKE AND DIP OF BEDDING (e).

Fig.2

PRINCIPLES OF THE BUILD UP OF THE SEDIMENTARY-VOLCANIC COMPLEXES OF THE POLMAK-PASVIK-PECHENGA-IMANDRA/VARZUGA-UST'PONOY GREENSTONE BELT





CORRELATION OF STRATIGRAPHIC COLUMNAR SECTIONS OF THE POLMAK-PASVIK-PECHENGA-IMANDRA/VARZUGA-UST'PONOY GREENSTONE BELT

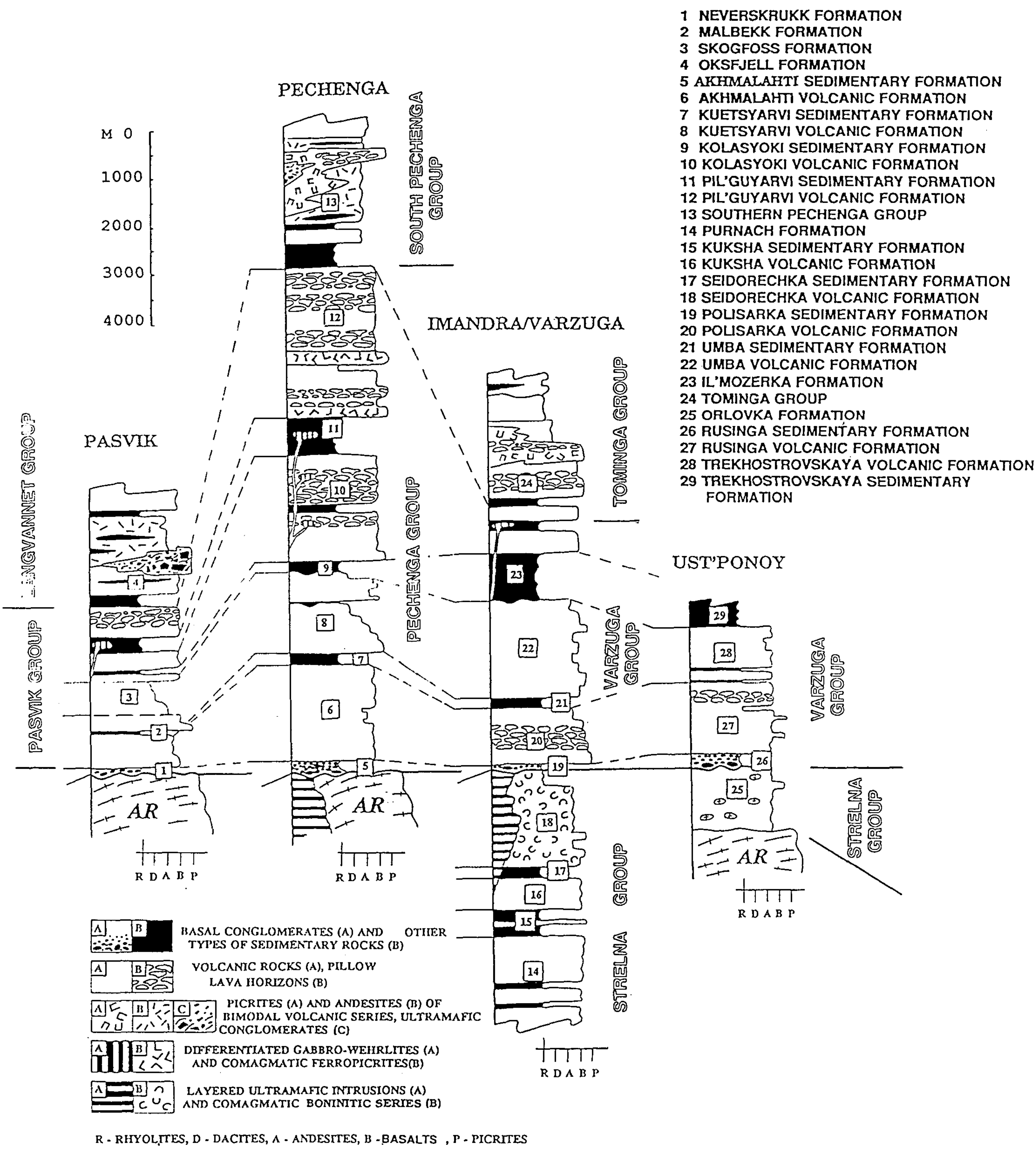
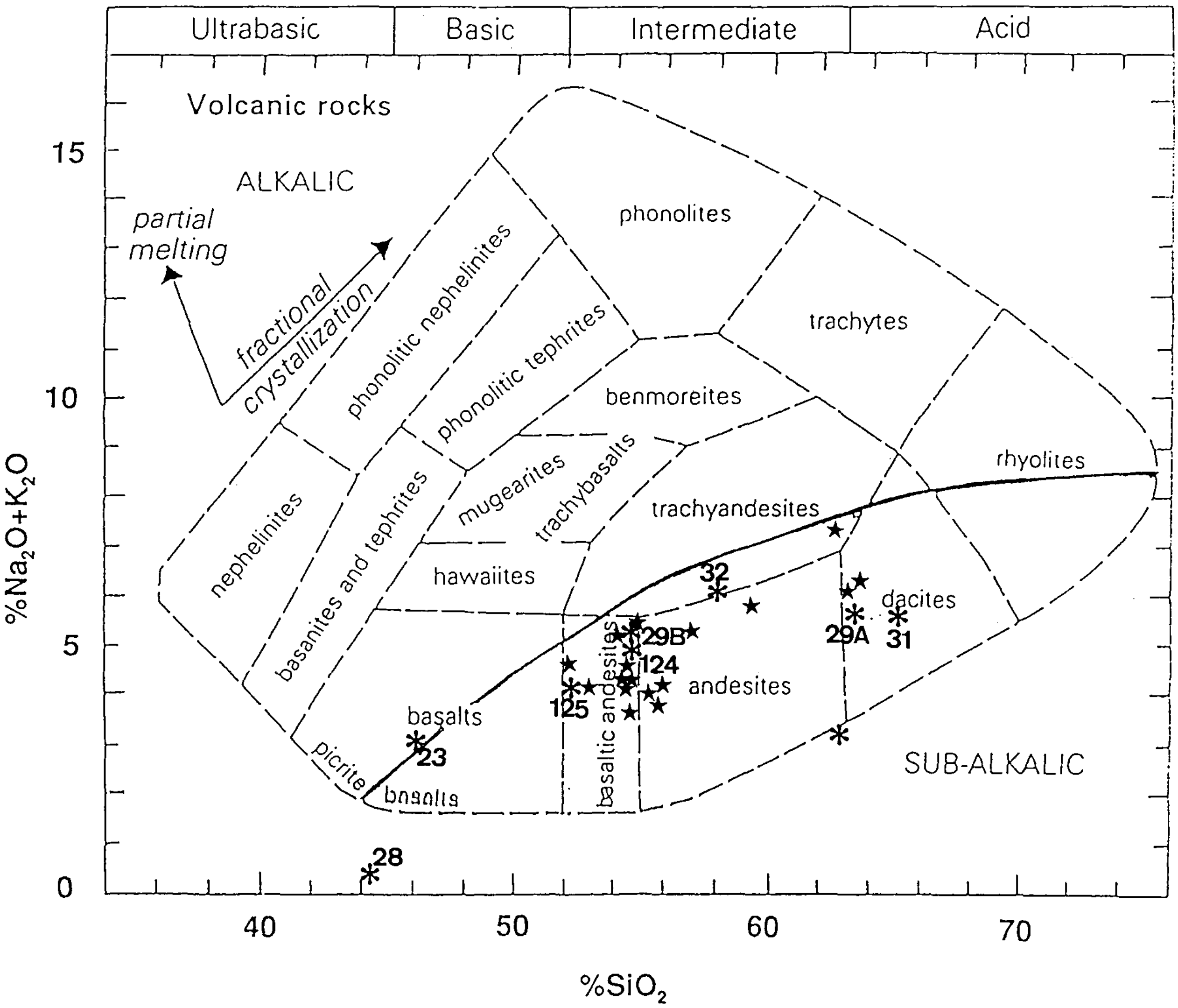


Fig.3

Fig.4

AKHMALAHTI AND BÅTTJØRNA VOLCANIC FORMATIONS



∗ Pechenga and Pasvik samples (this work)
★ Pechenga samples (Predovsky et al.1974)

Fig.5

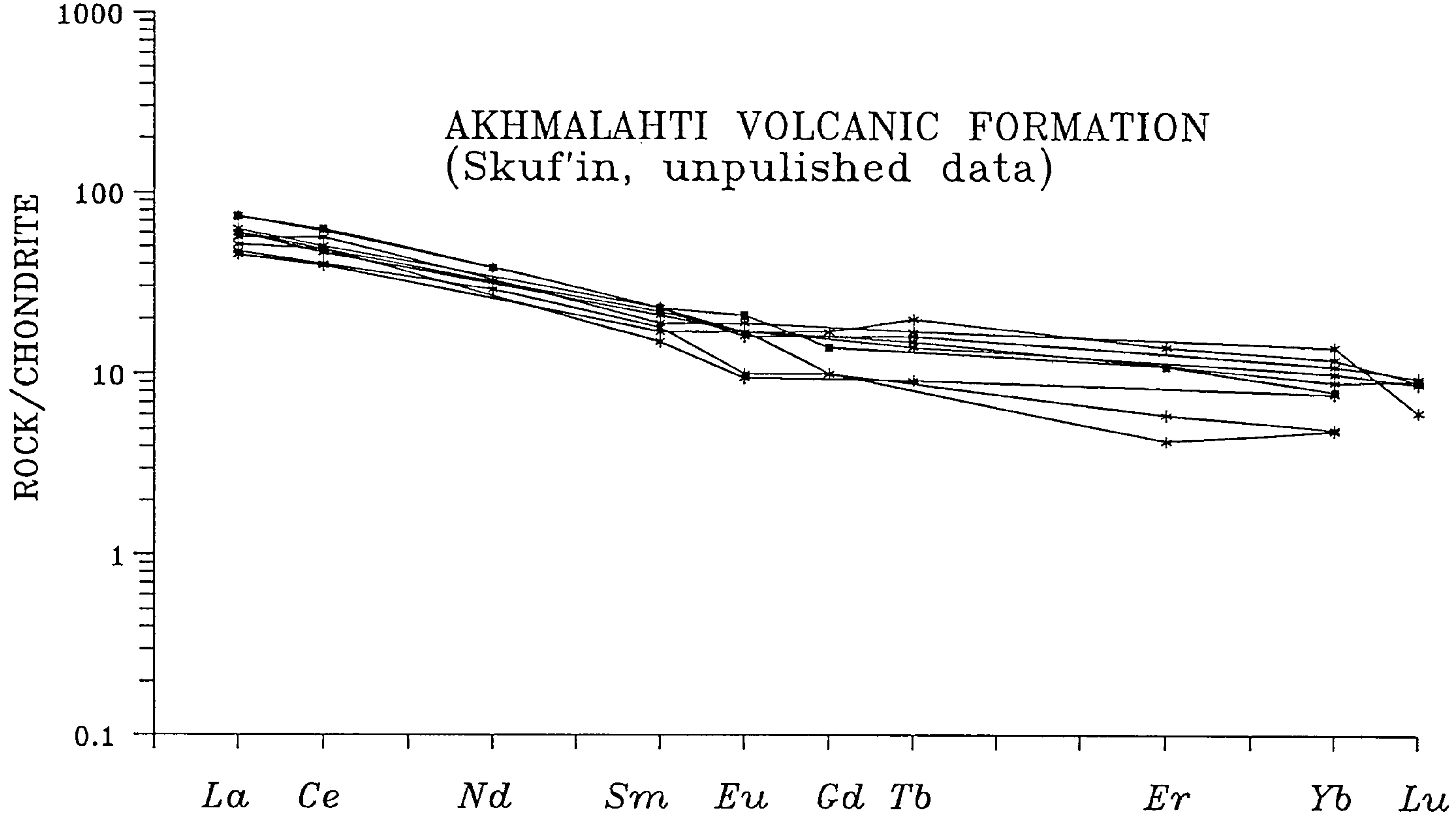
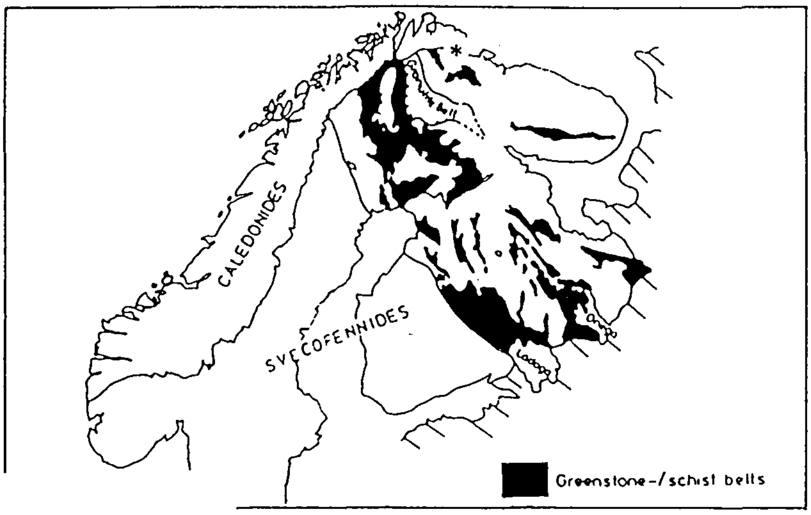
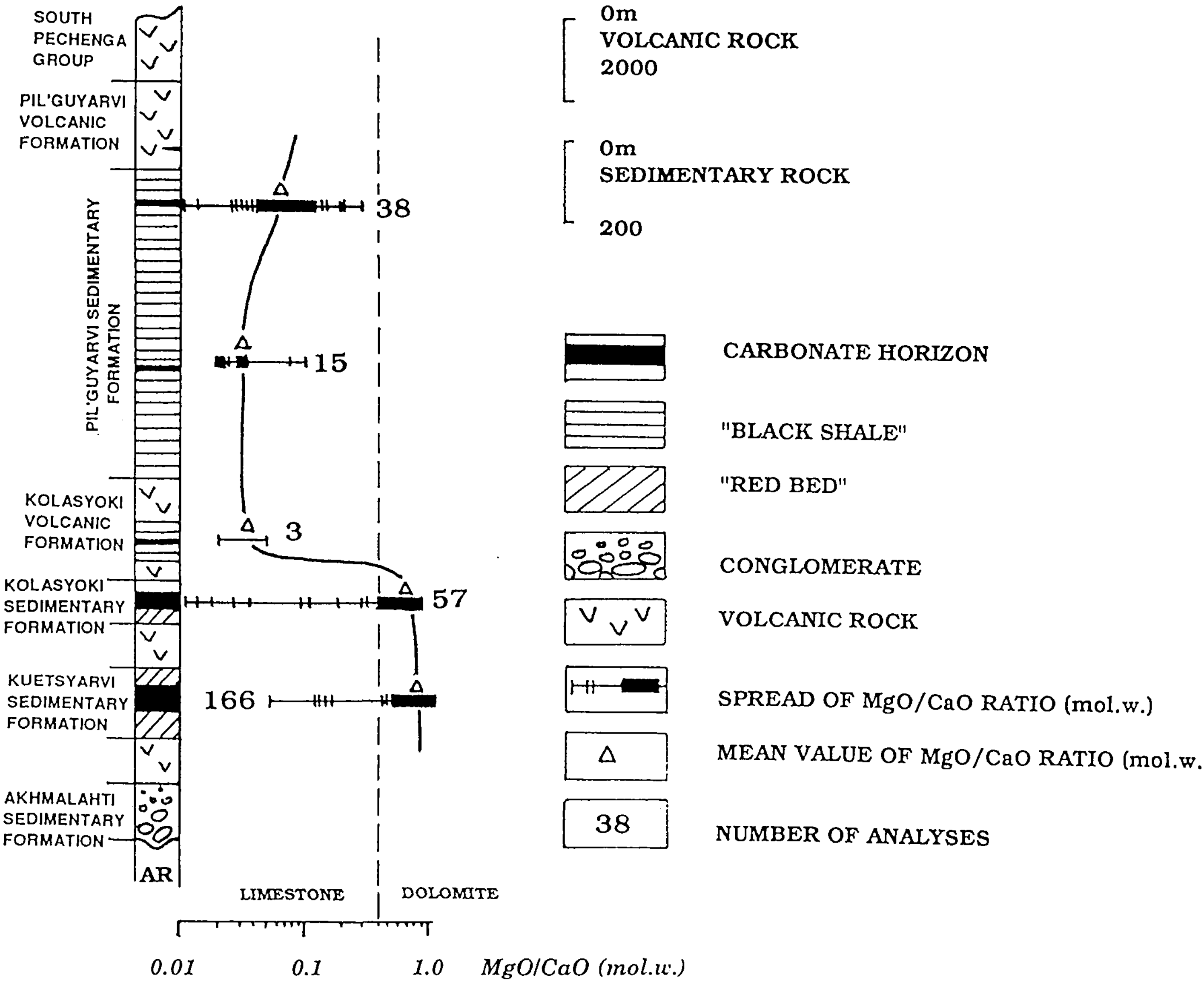

AKHMALAHTI VOLCANIC FORMATION
(Skuf'in, unpulished data)
ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.6

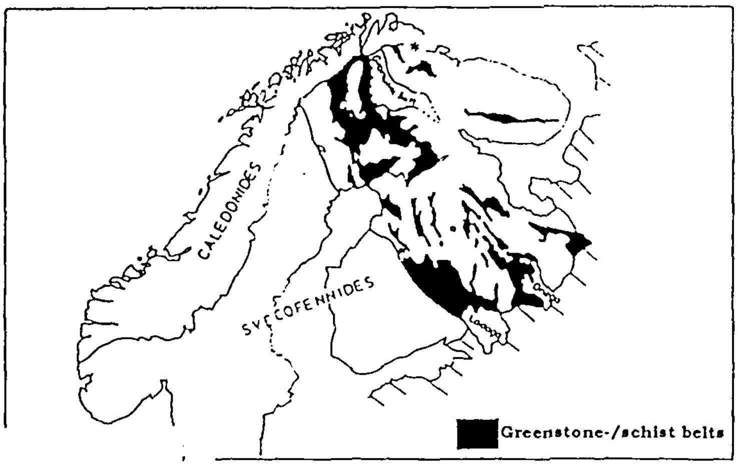


PECHENGA

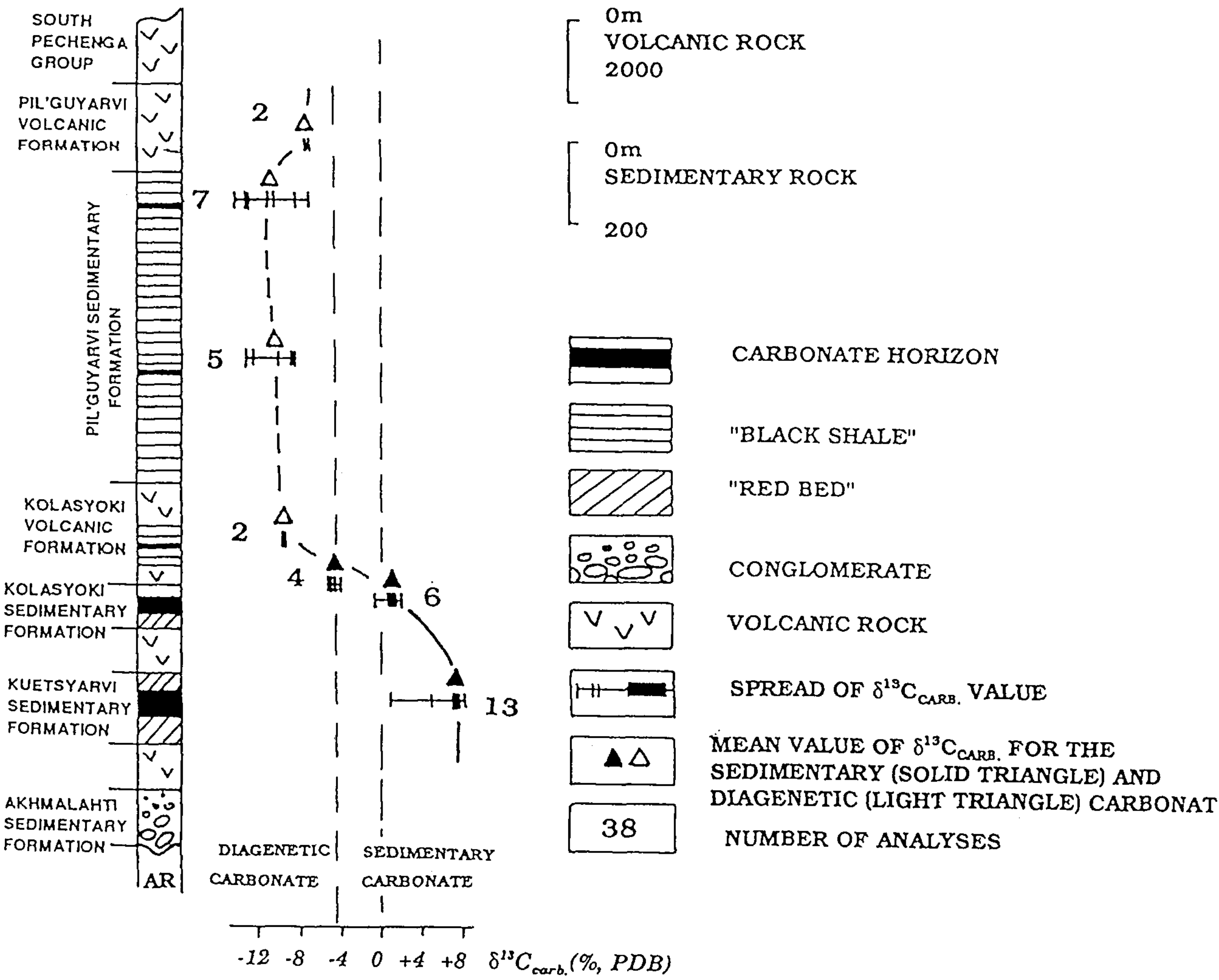


MgO/CaO RATIO VARIATIONS

Fig.7



PECHENGA



$\delta^{13}C_{CARB.}$ VALUE VARIATIONS

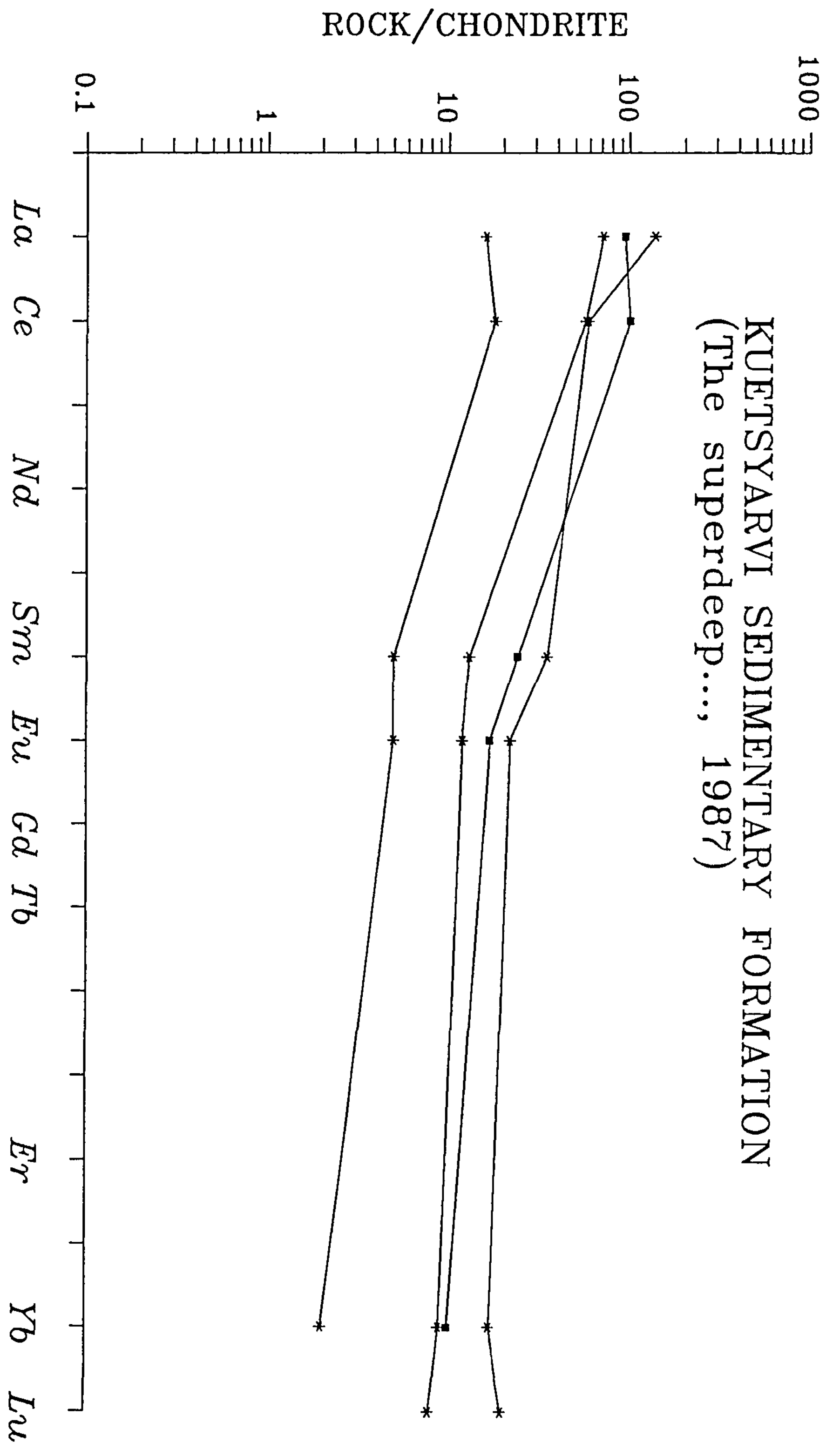
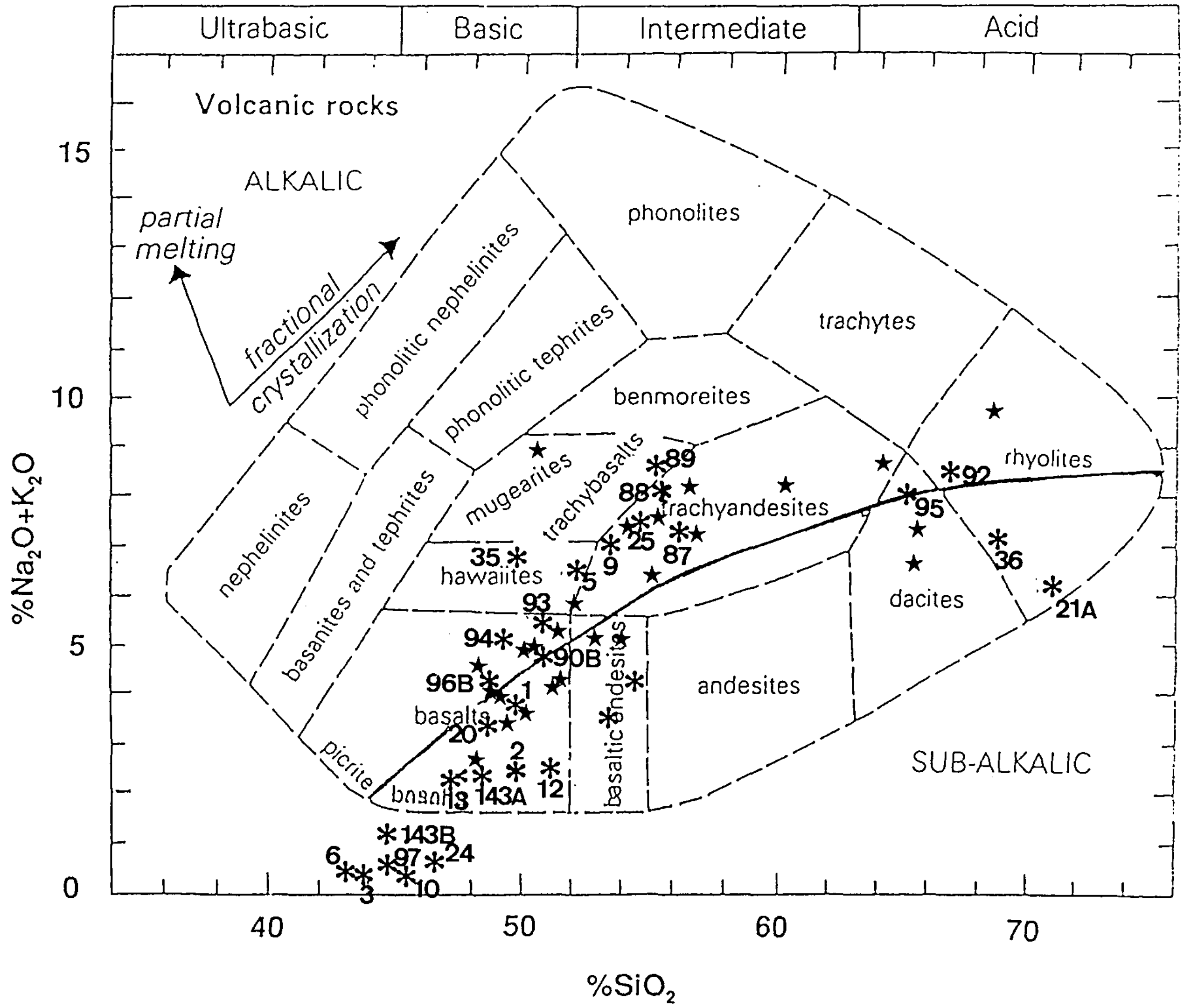

ROCK/CHONDRITE
0.1
1
10
100
1000
KUETSYARVI SEDIMENTARY FORMATION
(The superdeep..., 1987)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.8

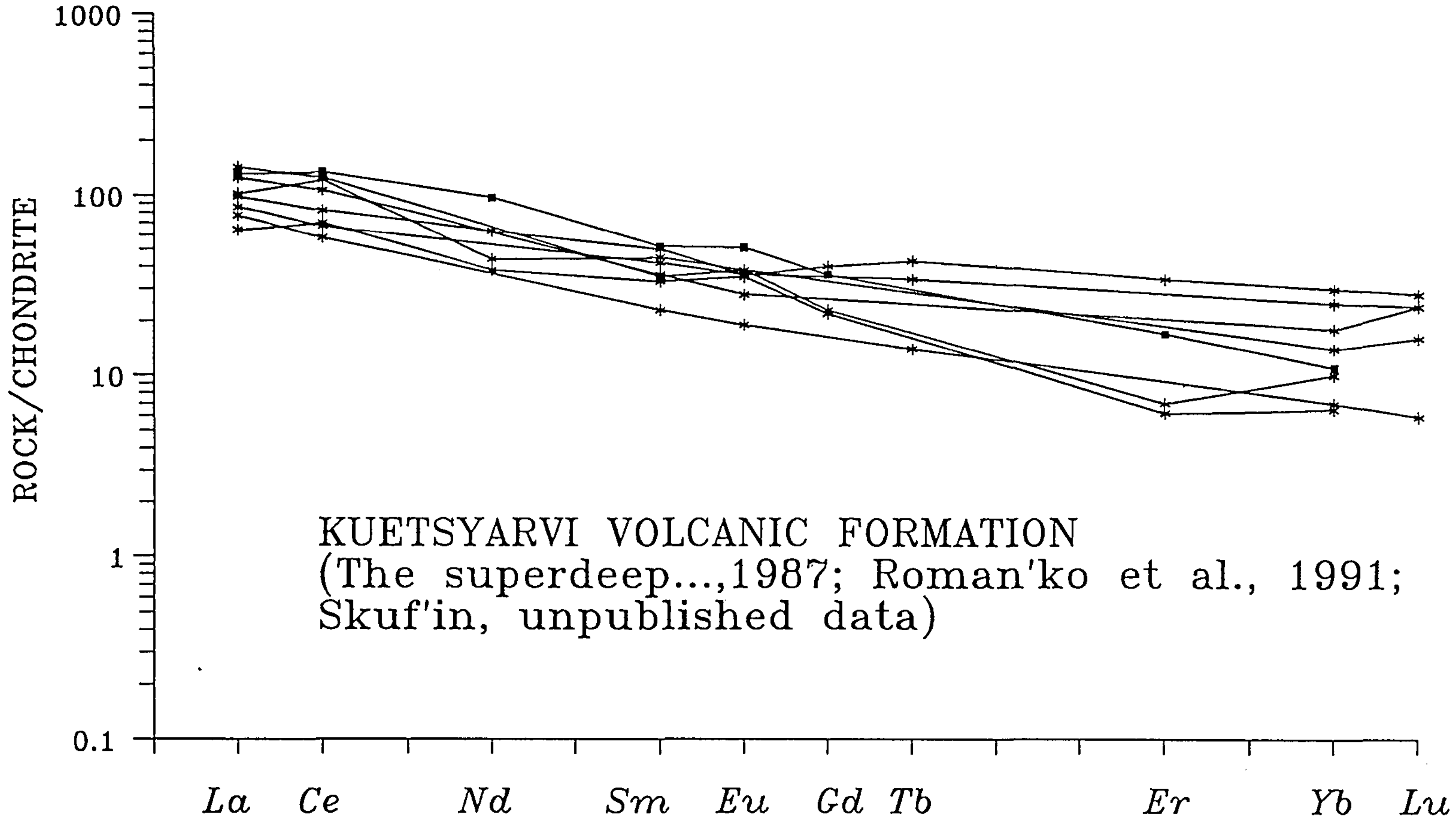
KUETSYARVI AND SKOGFOSS VOLCANIC FORMATIONS



∗ Pechenga and Pasvik samples (this work)
★ Pechenga samples (Predovsky et al.1974)

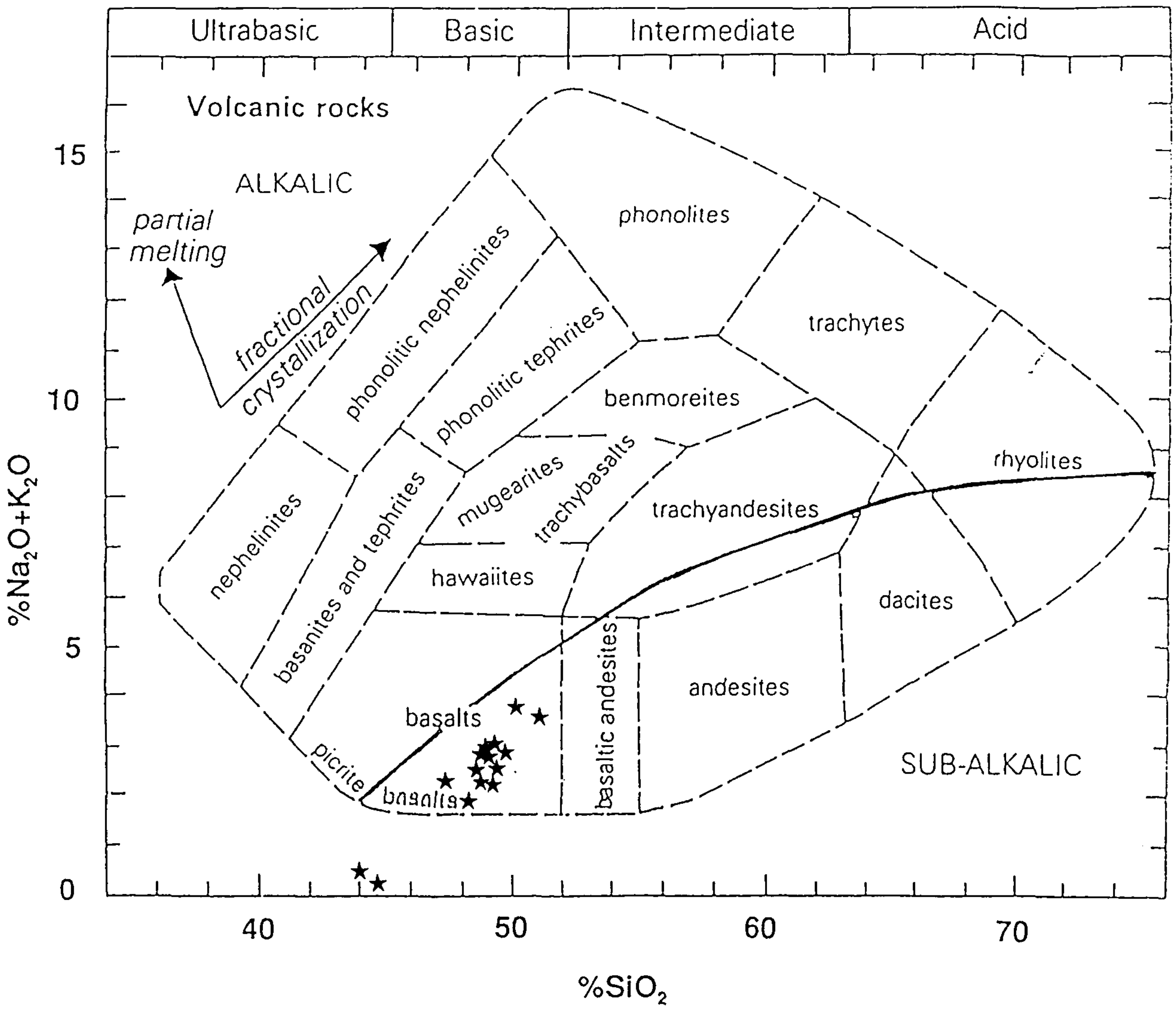
Fig.9

Fig.10



ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
KUETSYARVI VOLCANIC FORMATION
(The superdeep...,1987; Roman'ko et al., 1991;
Skuf'in, unpublished data)

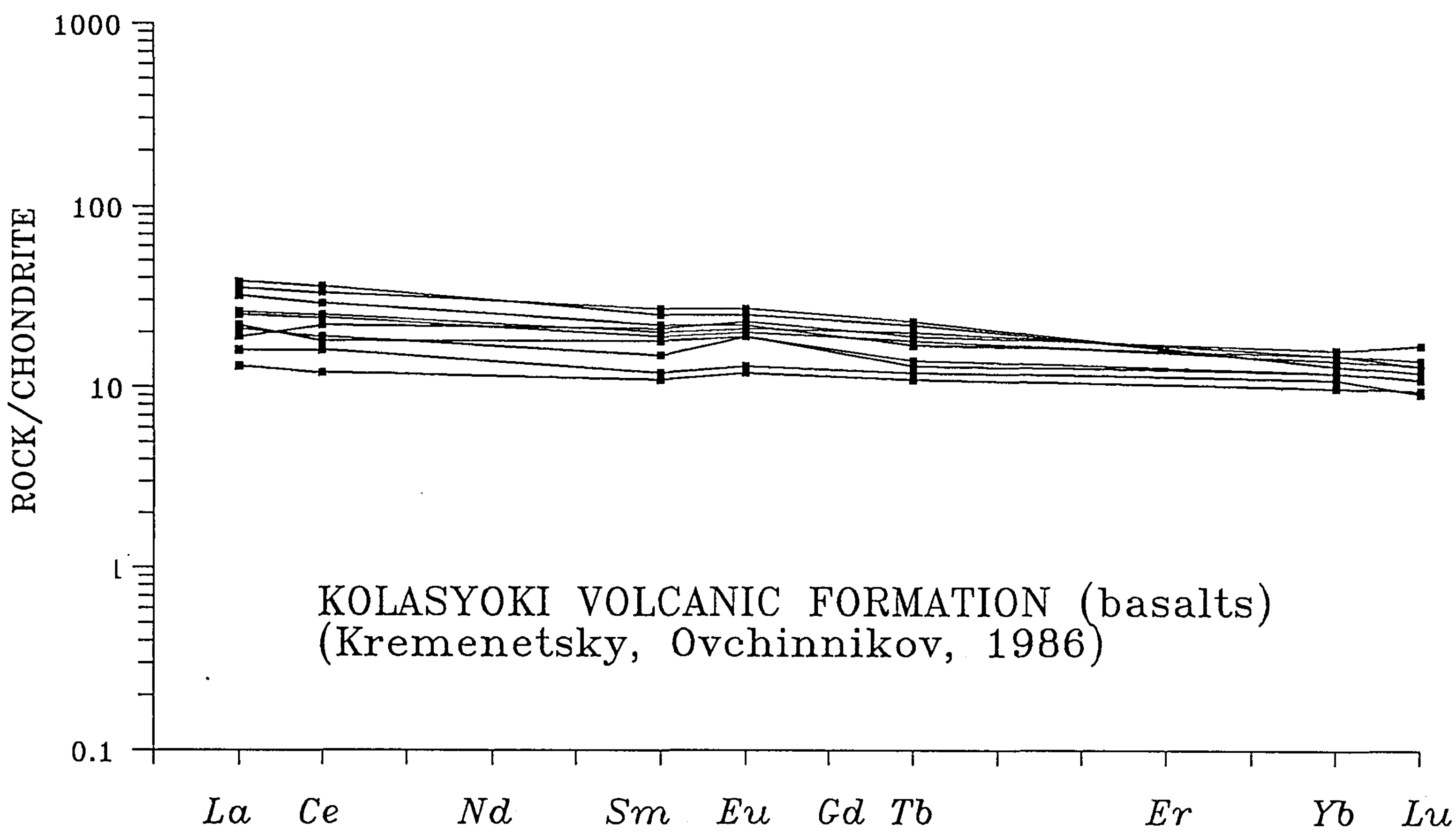
KOLASYOKI VOLCANIC FORMATION

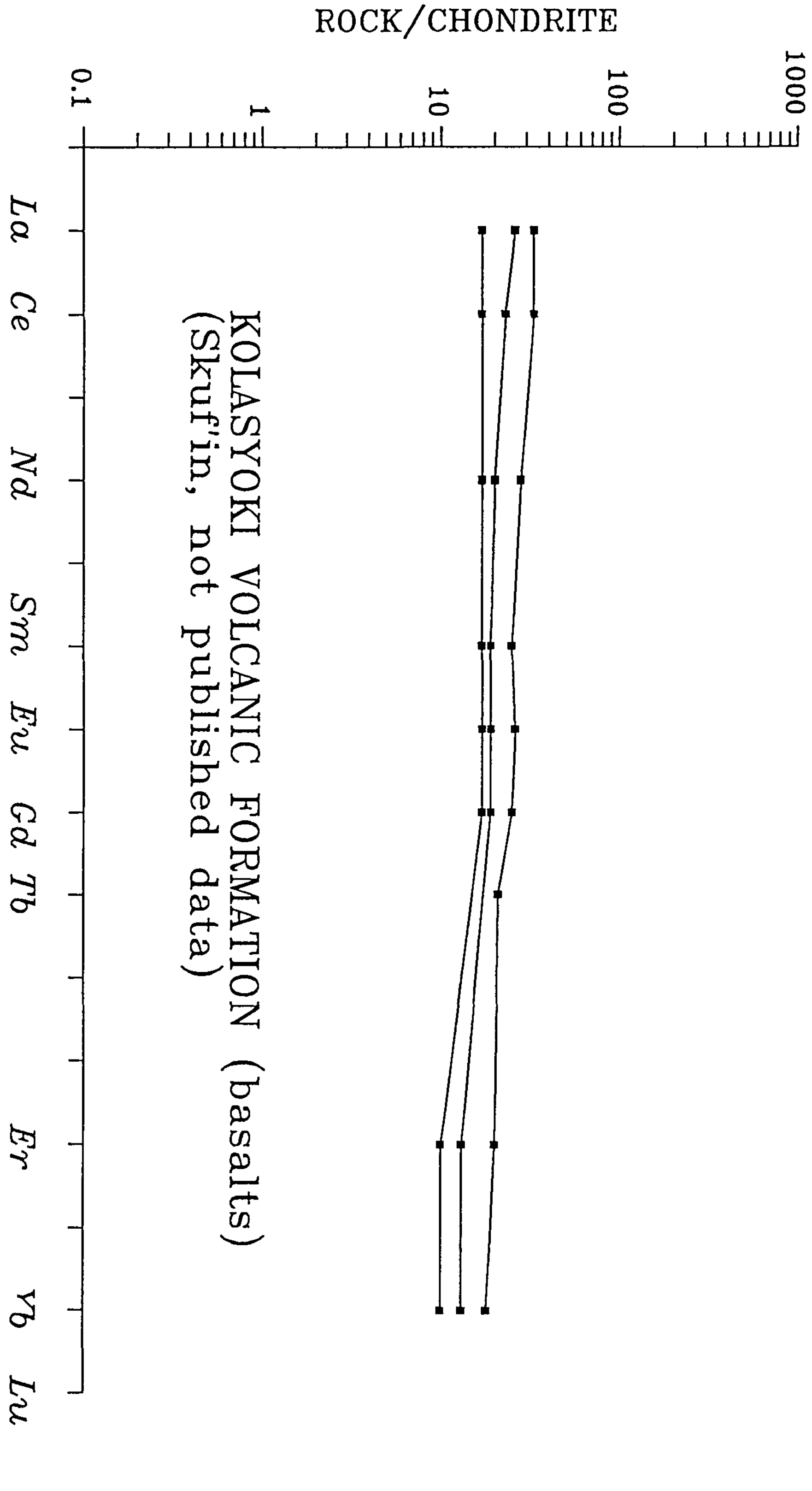


★ Pechenga samples (Predovsky et al.1974)

Fig.11

Fig.12


ROCK/CHONDRITE
1000
100
10
1
0.1
KOLASYOKI VOLCANIC FORMATION (basalts)
(Kremenetsky, Ovchinnikov, 1986)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu



ROCK/CHONDRITE
0.1
1
10
100
1000
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
KOLASYOKI VOLCANIC FORMATION (basalts)
(Skuf'in, not published data)

Fig.13

Fig.14

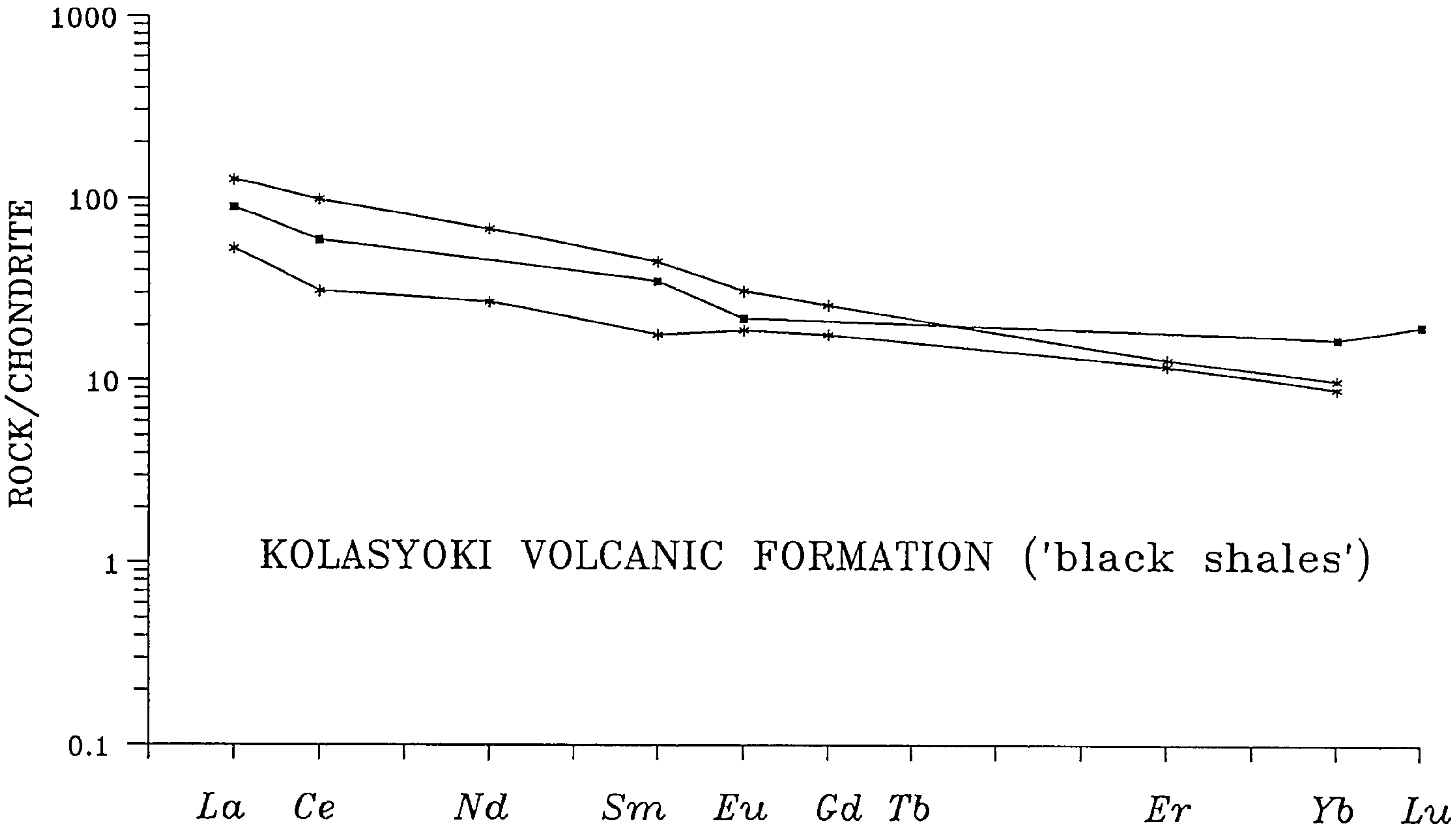
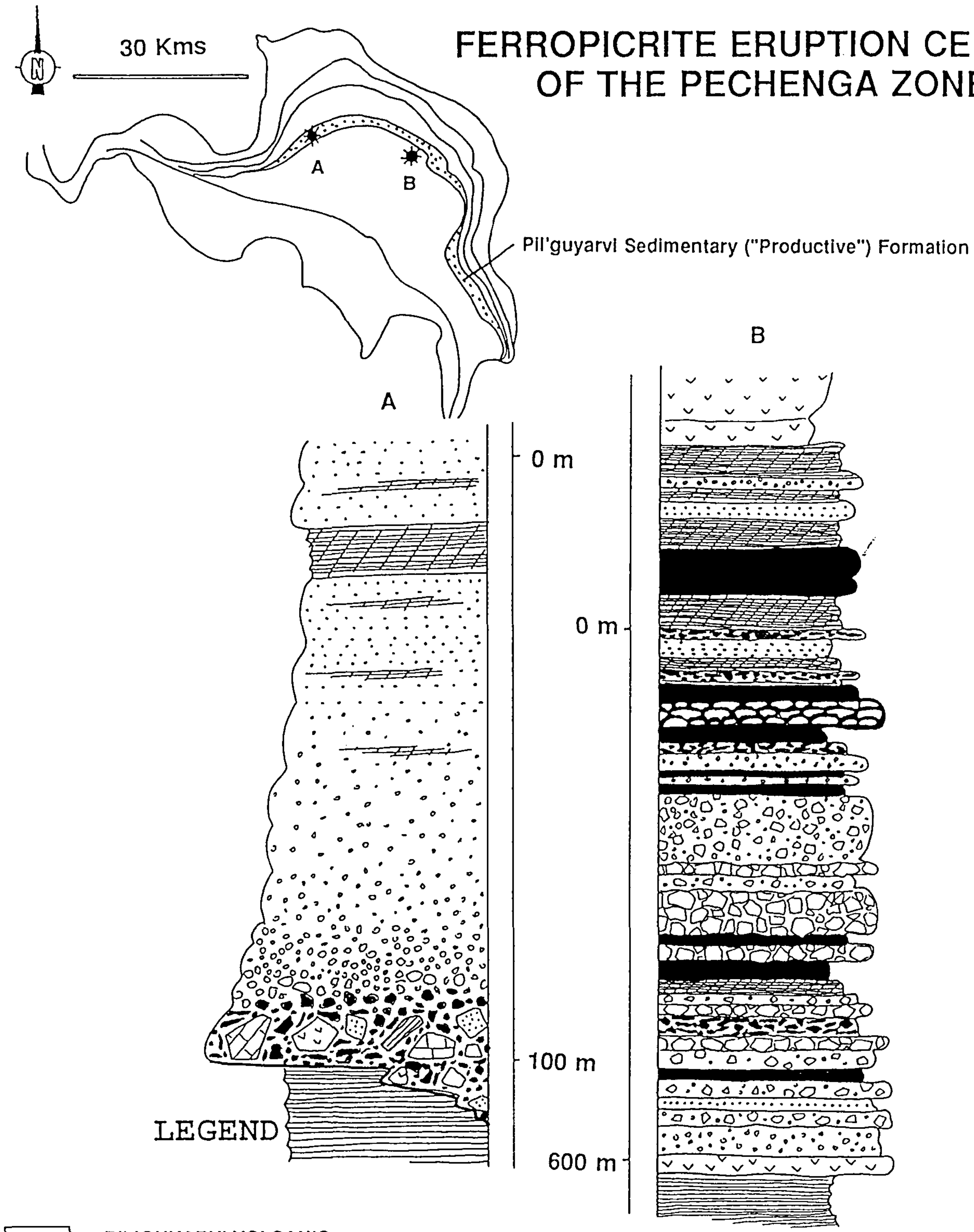

ROCK/CHONDRITE
1000
100
10
1
0.1
KOLASYOKI VOLCANIC FORMATION ('black shales')
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.15

FERROPICRITE ERUPTION CENTRES OF THE PECHENGA ZONE



LEGEND

PIL'GUYARVI VOLCANIC

MASSIVE LAVA OF FERROPICRITE

PILLOW-LAVA OF FERROPICRITE

LAVA BRECCIA OF FERROPICRITE

TUFF BRECCIA OF FERROPICRITE

FERROPICRITIC AGGLOMERATE WITH FRAGMENTS OF BASALT, LIMESTONE AND QUARTZITIC SANDSTONE

COARSE-GRAINED FERROPICRITIC TUFF

MEDIUM-GRAINED FERROPICRITIC TUFF

FINE-GRAINED FERROPICRITIC TUFF

MEDIUM-GRAINED FERROPICRITIC CARBON- AND SULPHER-BEARING TUFFITE

FINE-GRAINED FERROPICRITIC CARBON- AND SULPHER-BEARING TUFFITE

"BLACK SHALE" OF THE "PRODUCTIVE" FORMATION

Fig.16

FERROPICRITE ERUPTION CENTRES OF THE PECHENGA ZONE

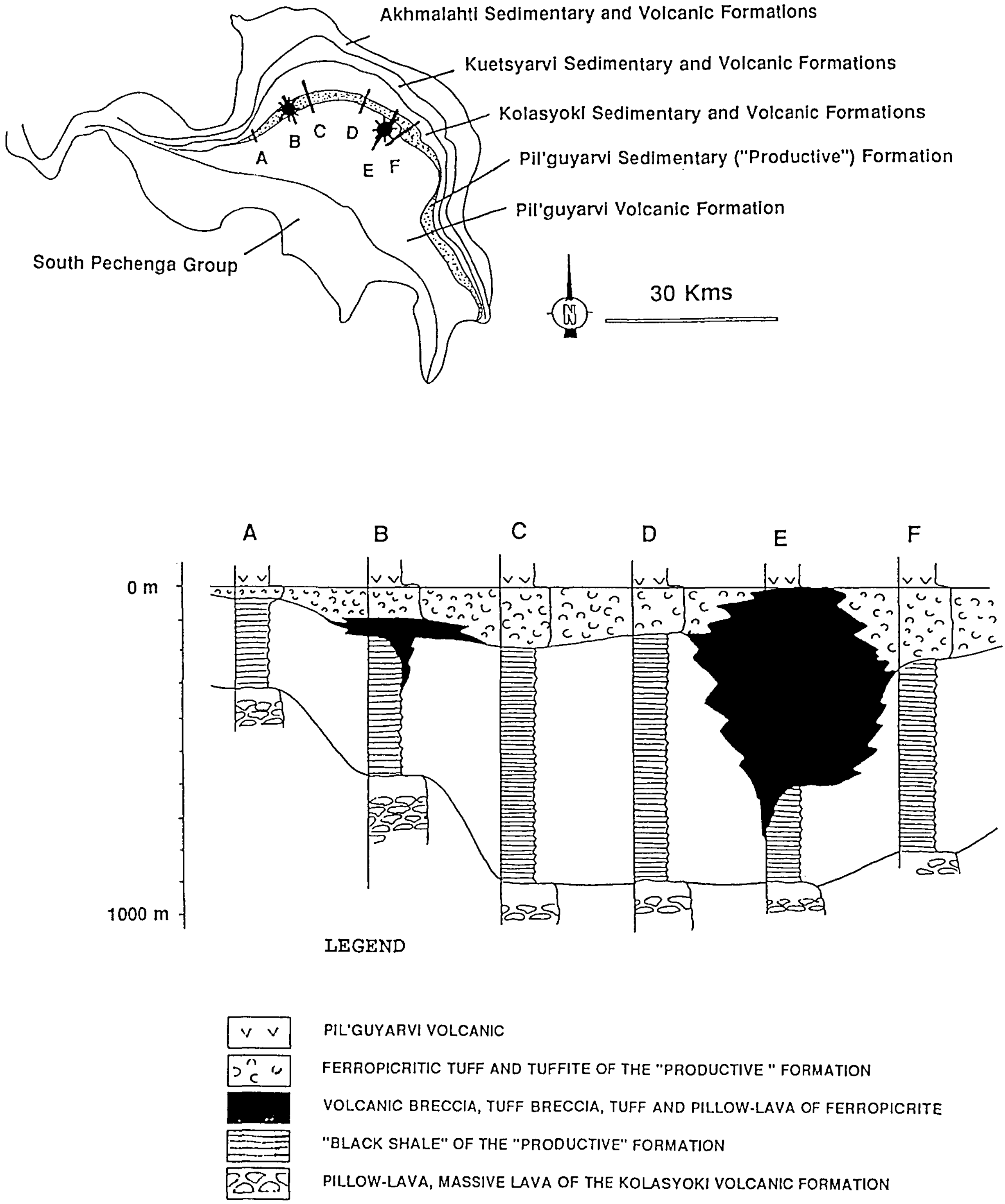
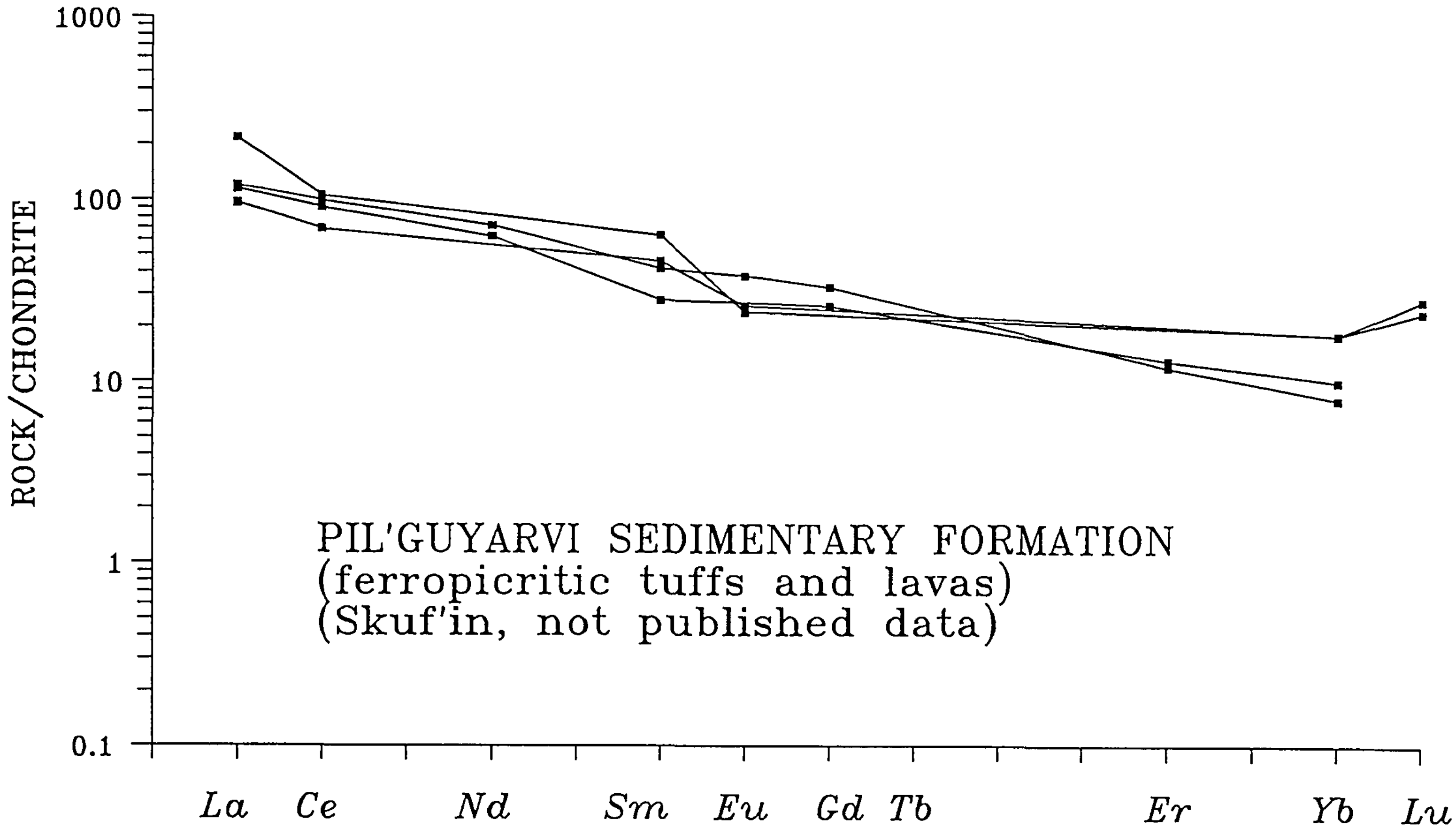
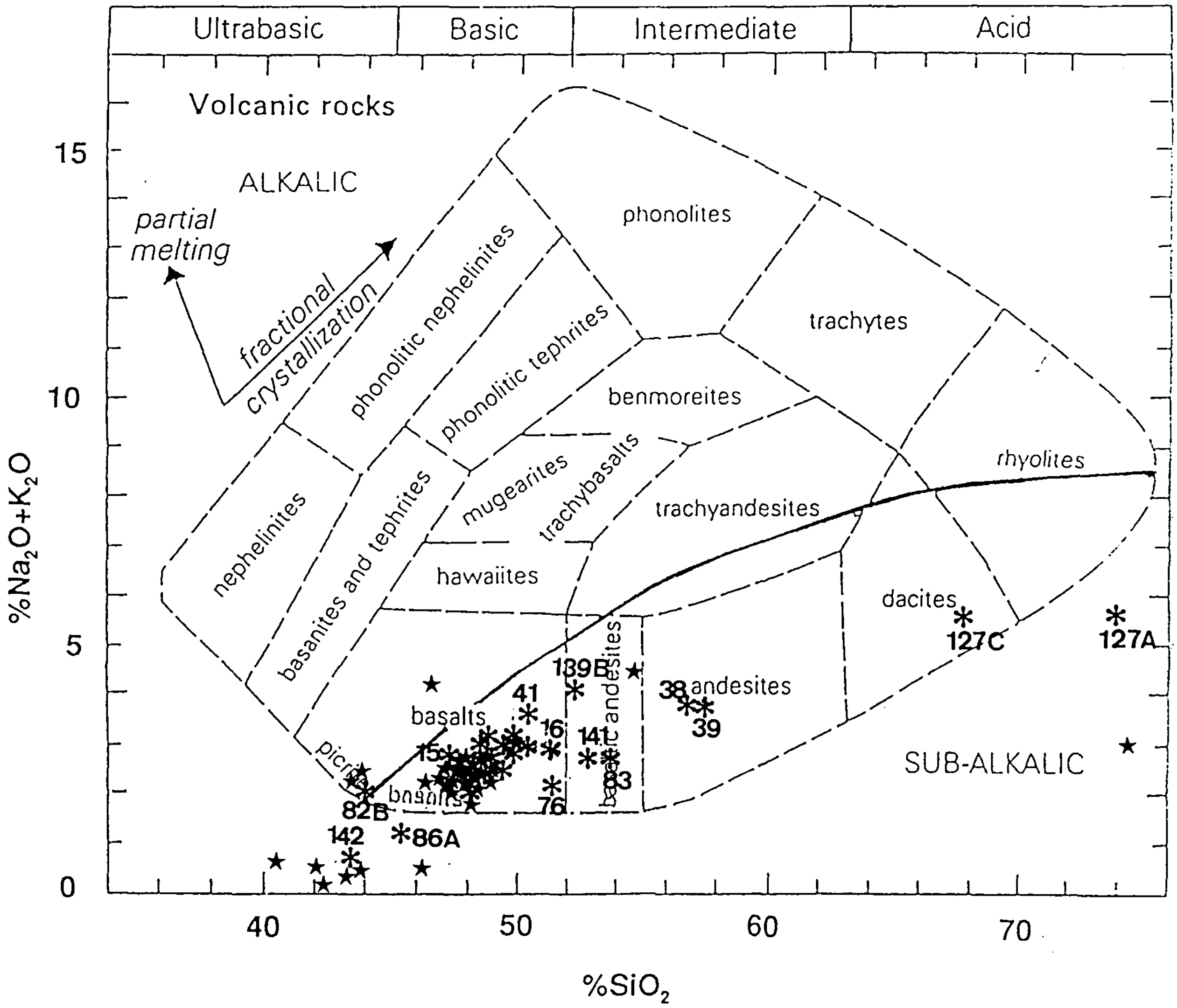


Fig.17


ROCK/CHONDRITE
1000
100
10
1
0.1
PIL'GUYARVI SEDIMENTARY FORMATION
(ferropicritic tuffs and lavas)
(Skuf'in, not published data)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

PILGUYARVI AND KILTJØRNAN VOLCANIC FORMATIONS

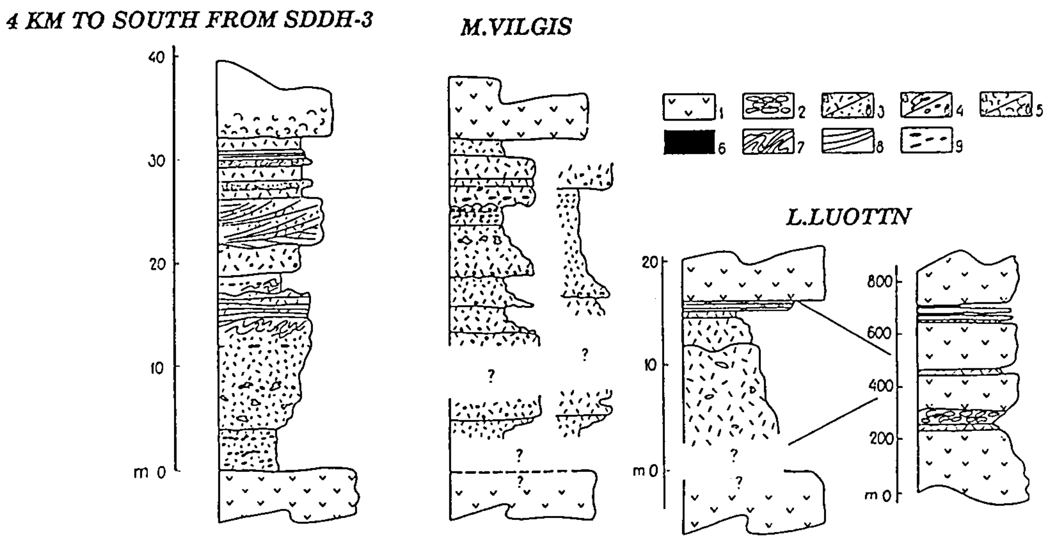


∗ Pechenga and Pasvik samples (this work)
★ Pechenga samples (Predovsky et al.1974)

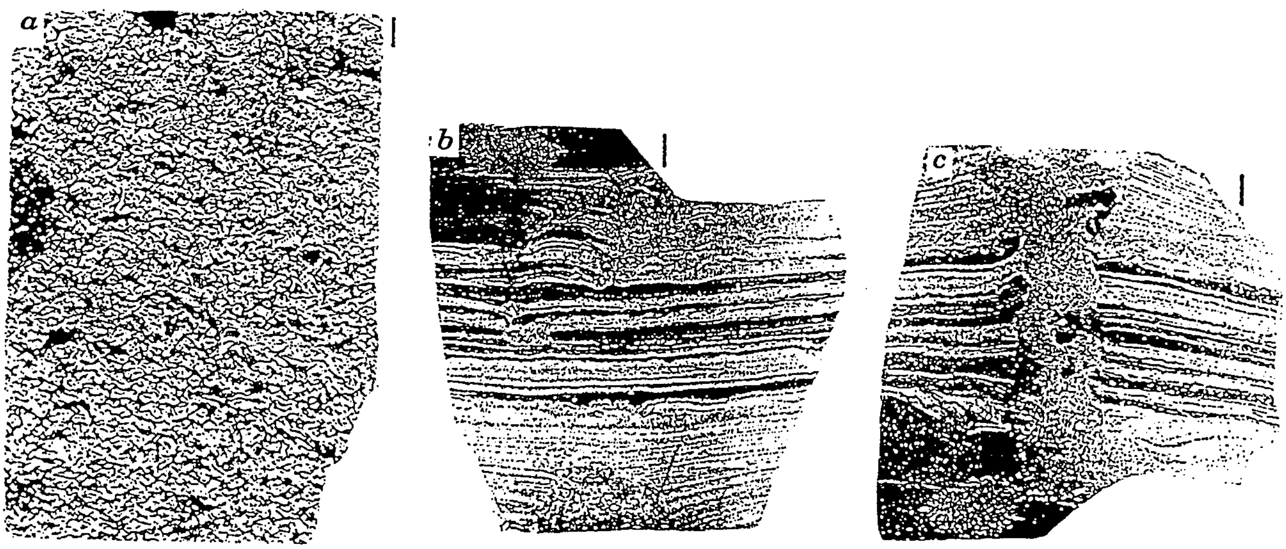
Fig.18

PIL'GUJARVY VOLCANIC FORMATION

HORIZON OF RHYOLITIC TUFFS



1 - BASALTS; 2 - PILLOW LAVA; 3 - SUBAERIAL COARSE-GRAINED (a) AND FINE-GRAINED (b) RHYOLITIC TUFFS; 4 - VOLCANIC BOMBS; 5 - FINE-GRAINED (a) AND COARSE-GRAINED (b) BASALT TUFFS; 6 - "BLACK SHALES"; 7 - SYNSEDIMENTARY FOLDING; 8 - CROSS-BEDDING;
9 - CALCAREOUS CONCRETIONS



a - AERIAL COARSE-GRAINED RHYOLITIC TUFF; b - SYNSEDIMENTARY FOLDING IN FINE-GRAINED RHYOLITIC TUFF; c - SYNSEDIMENTARY DIKE IN FINE-GRAINED RHYOLITIC TUFF.

Fig.19

Fig.20

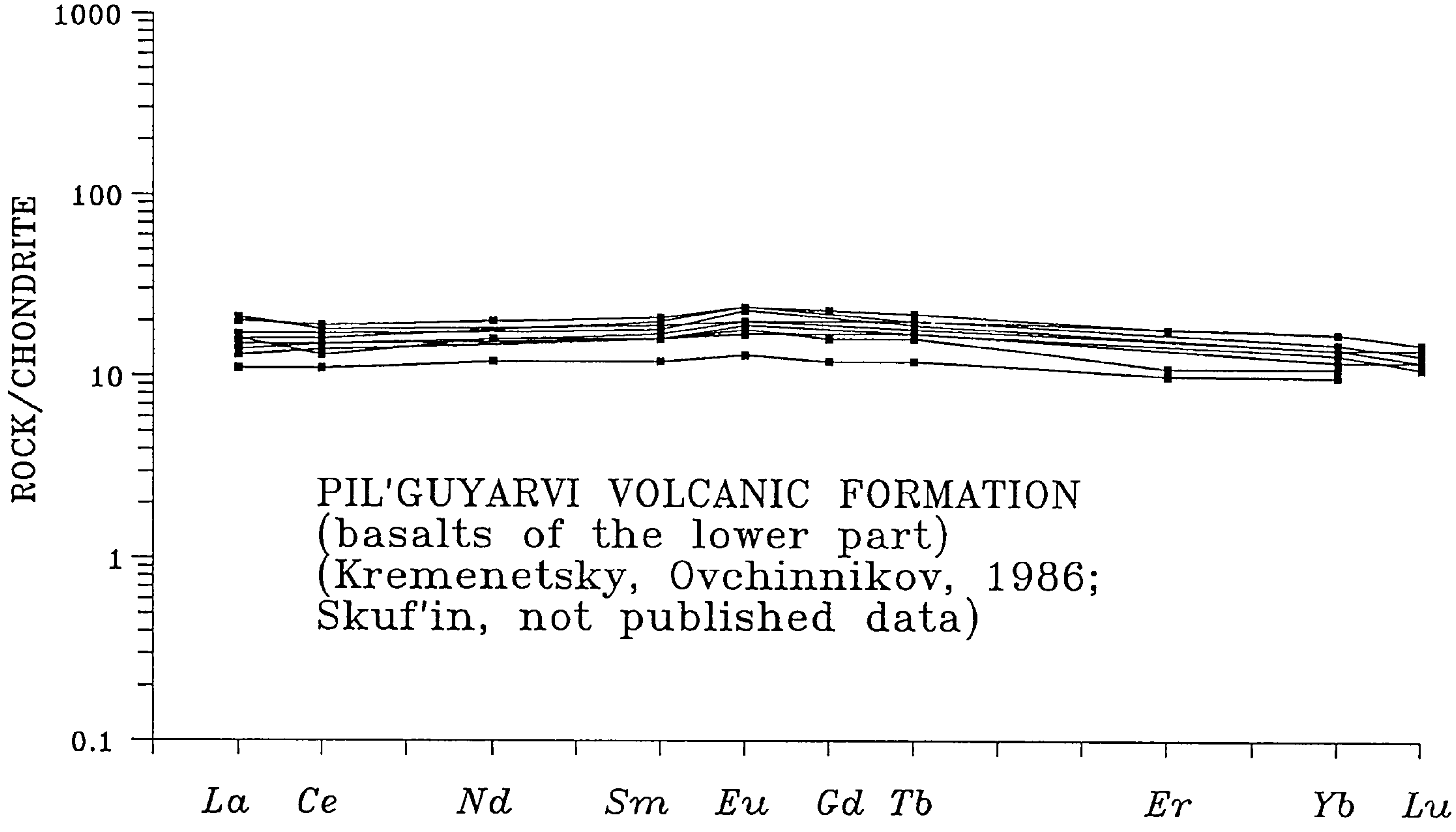

ROCK/CHONDRITE
1000
100
10
1
0.1
PIL'GUYARVI VOLCANIC FORMATION
(basalts of the lower part)
(Kremenetsky, Ovchinnikov, 1986;
Skuf'in, not published data)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.21

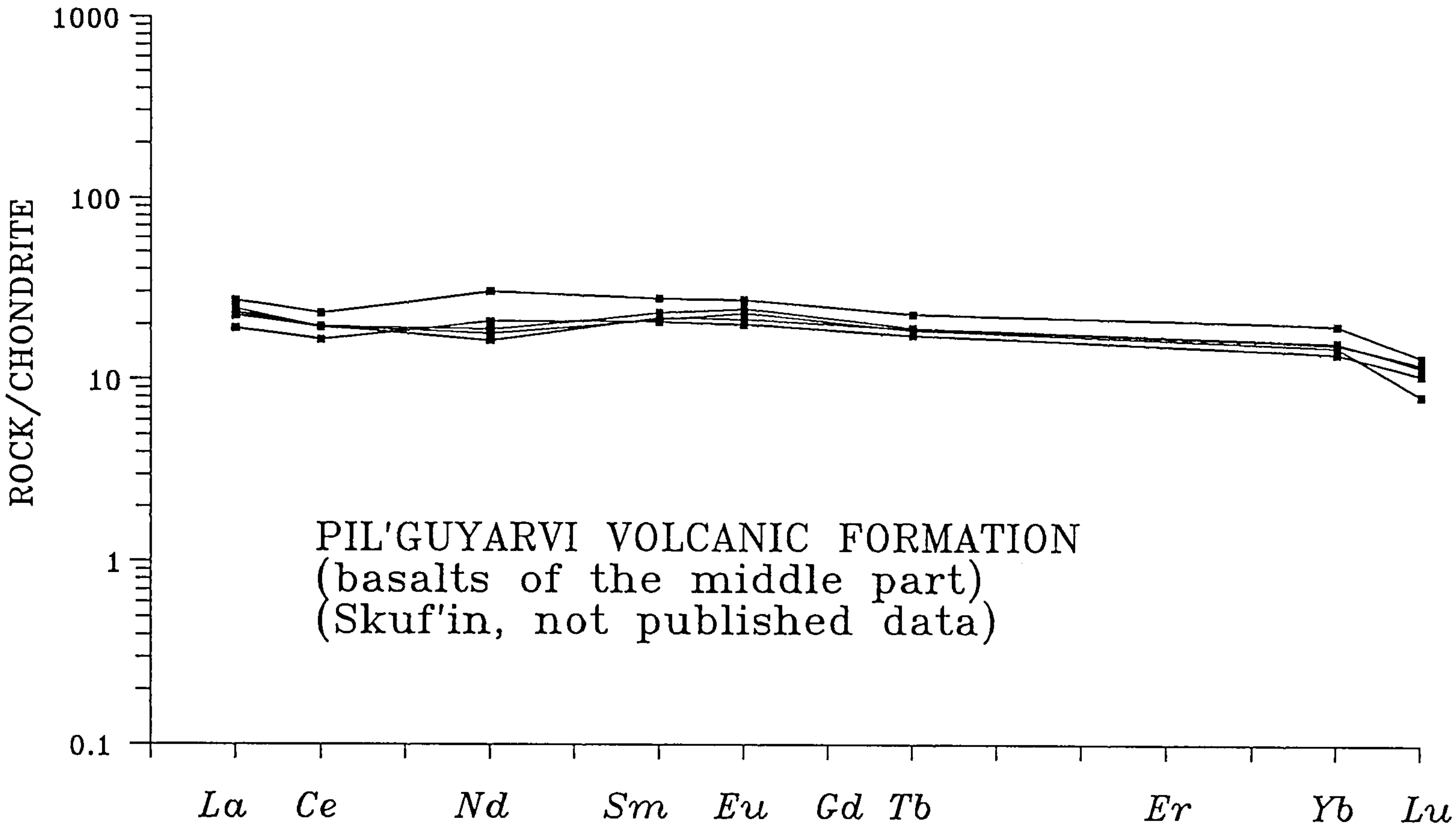

ROCK/CHONDRITE
1000
100
10
1
0.1
PIL'GUYARVI VOLCANIC FORMATION
(basalts of the middle part)
(Skuf'in, not published data)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.22

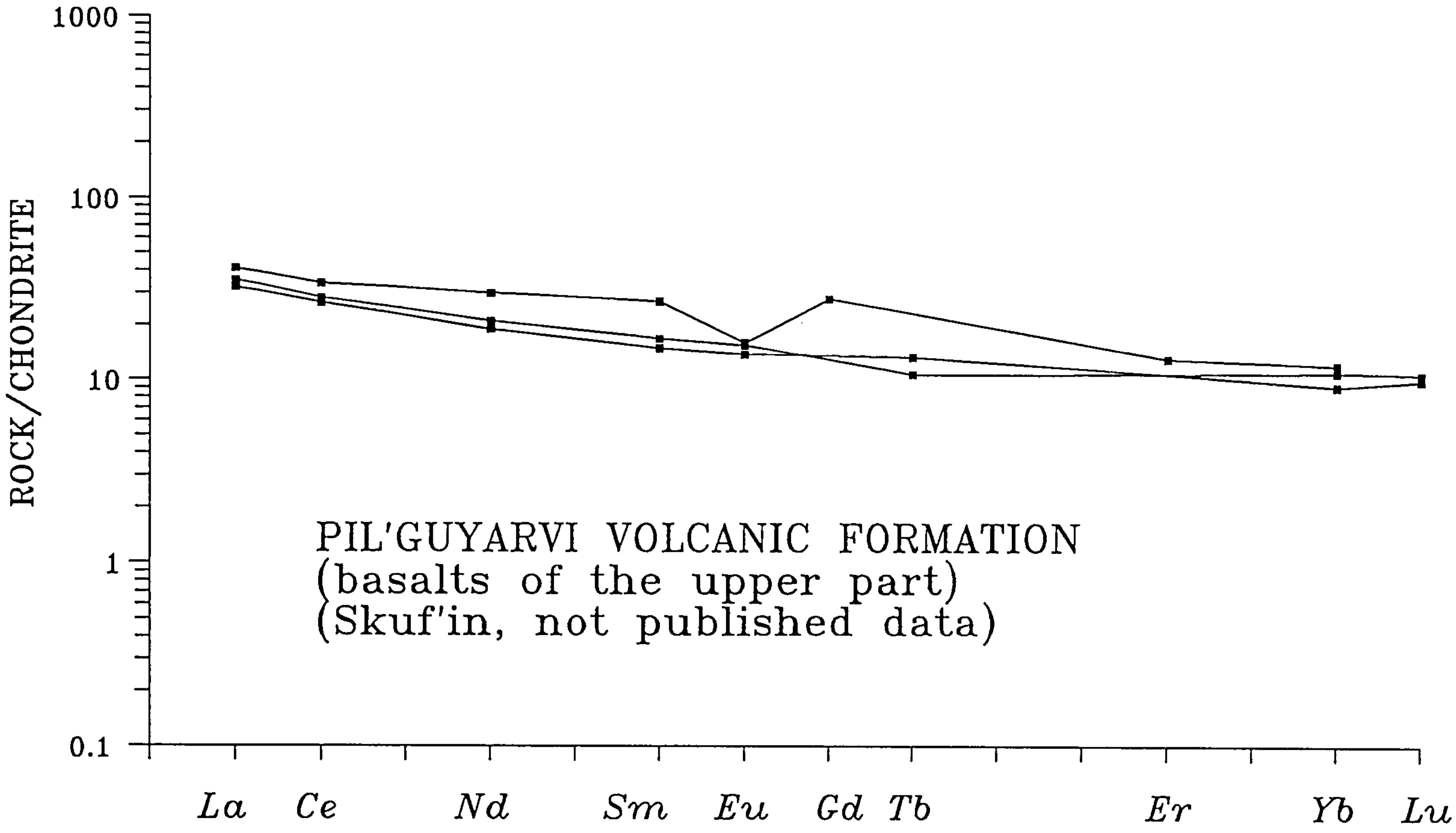

ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
PIL'GUYARVI VOLCANIC FORMATION
(basalts of the upper part)
(Skuf'in, not published data)

Fig.23

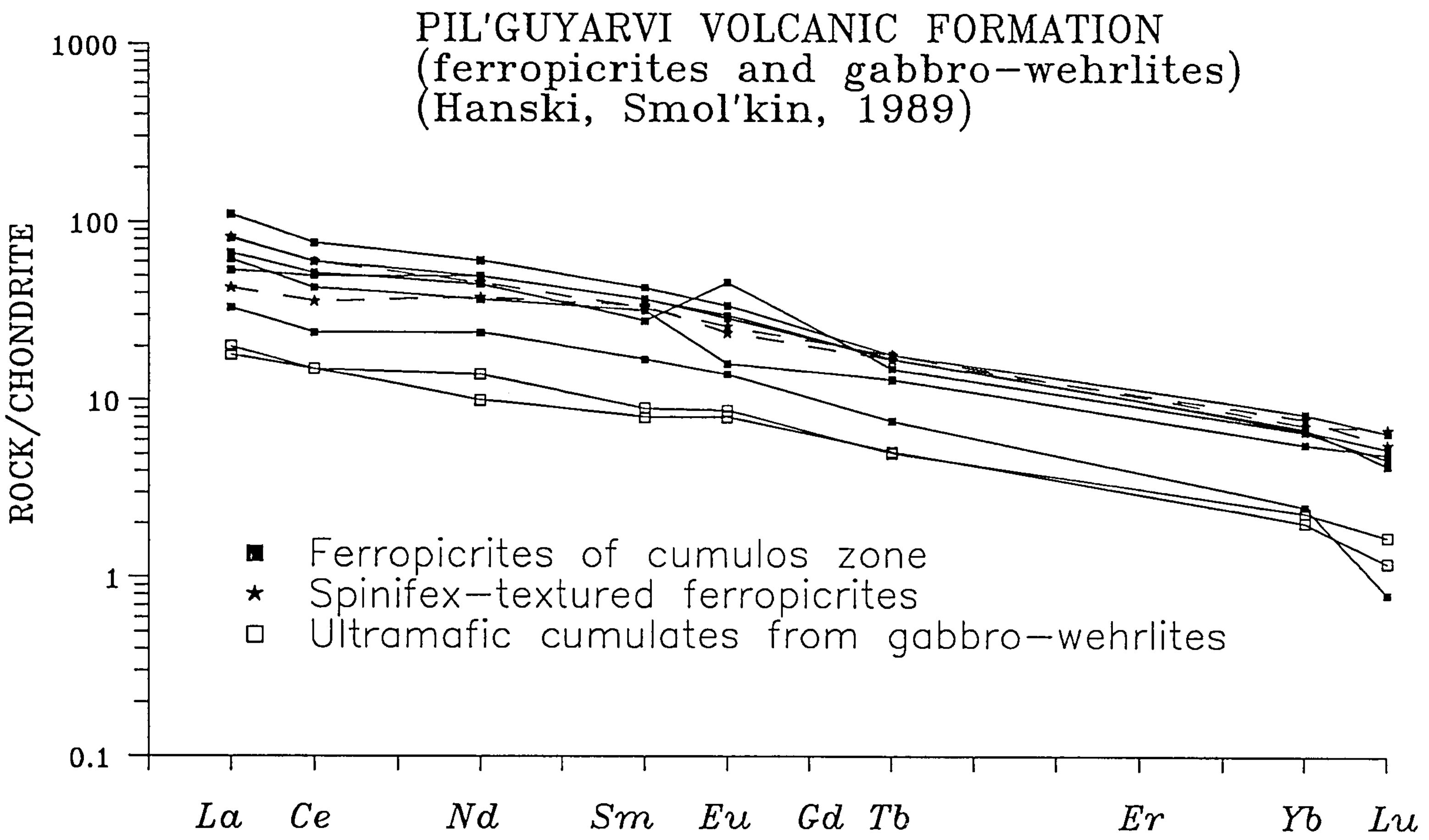

PIL'GUYARVI VOLCANIC FORMATION
(ferropicrites and gabbro-wehrlites)
(Hanski, Smol'kin, 1989)
ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
Ferropicrites of cumulos zone
Spinifex-textured ferropicrites
Ultramafic cumulates from gabbro-wehrlites

Fig.24

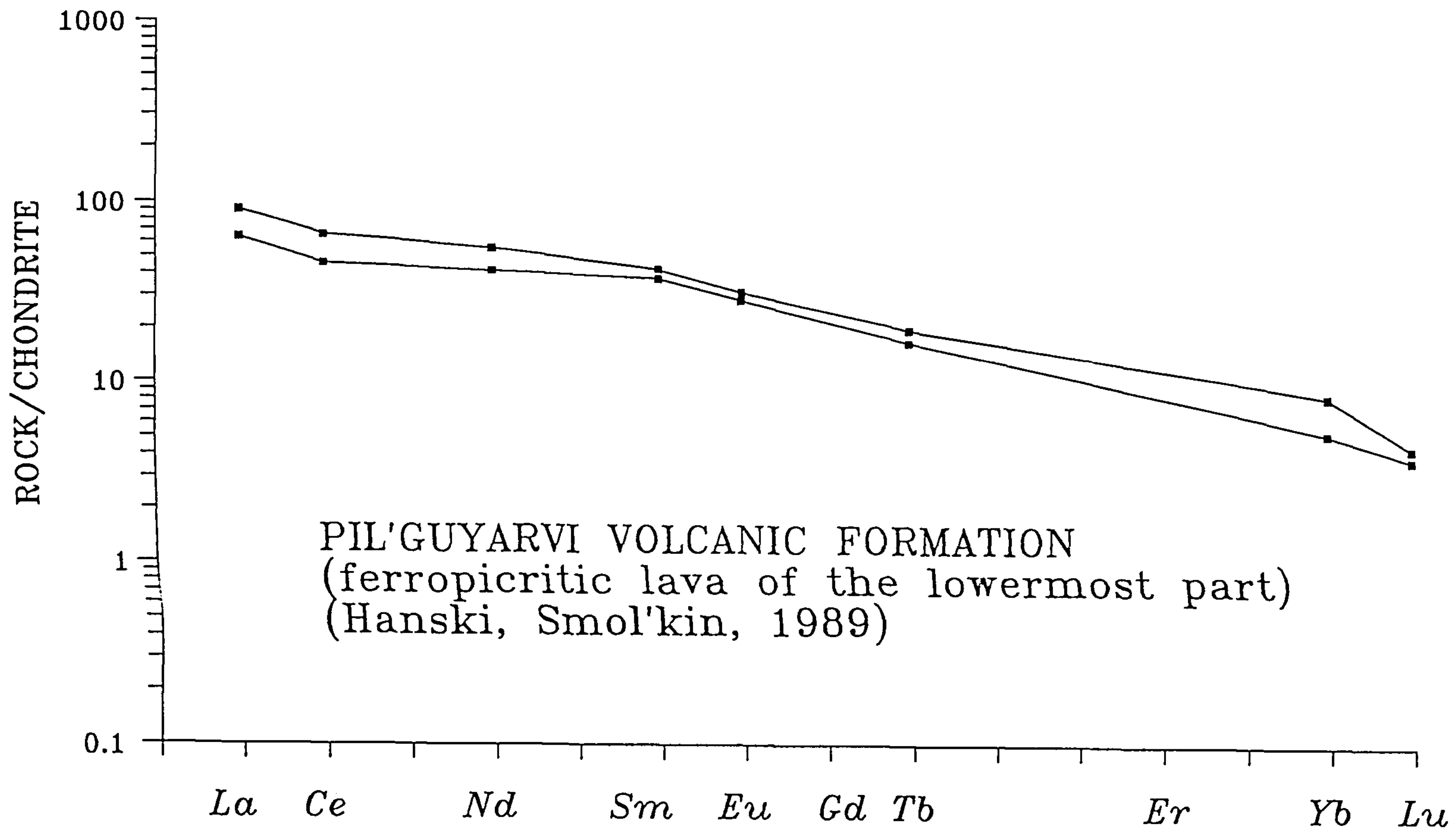

1000
100
10
1
0.1
ROCK/CHONDRITE
PIL'GUYARVI VOLCANIC FORMATION
(ferropicritic lava of the lowermost part)
(Hanski, Smol'kin, 1989)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.25

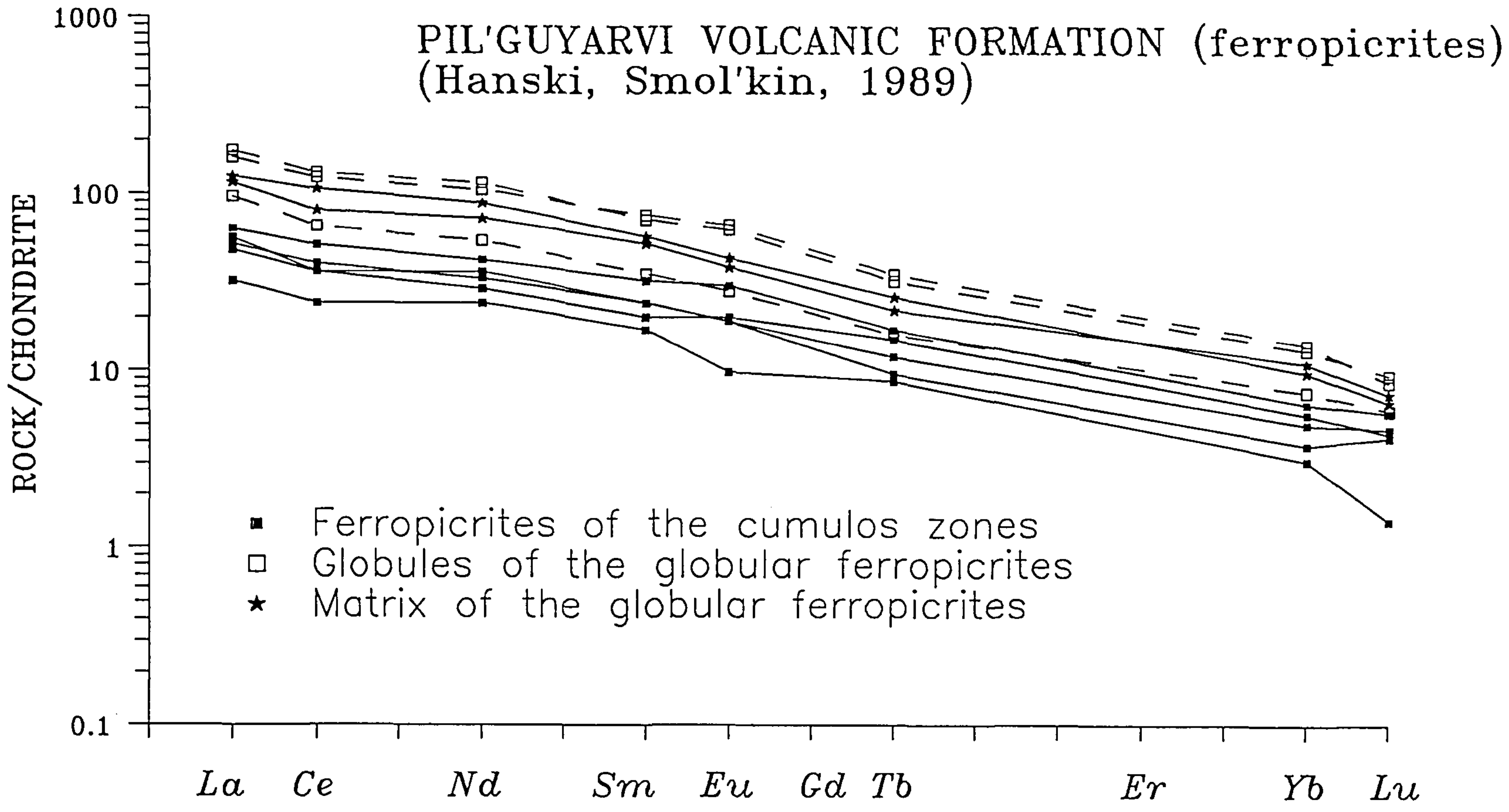
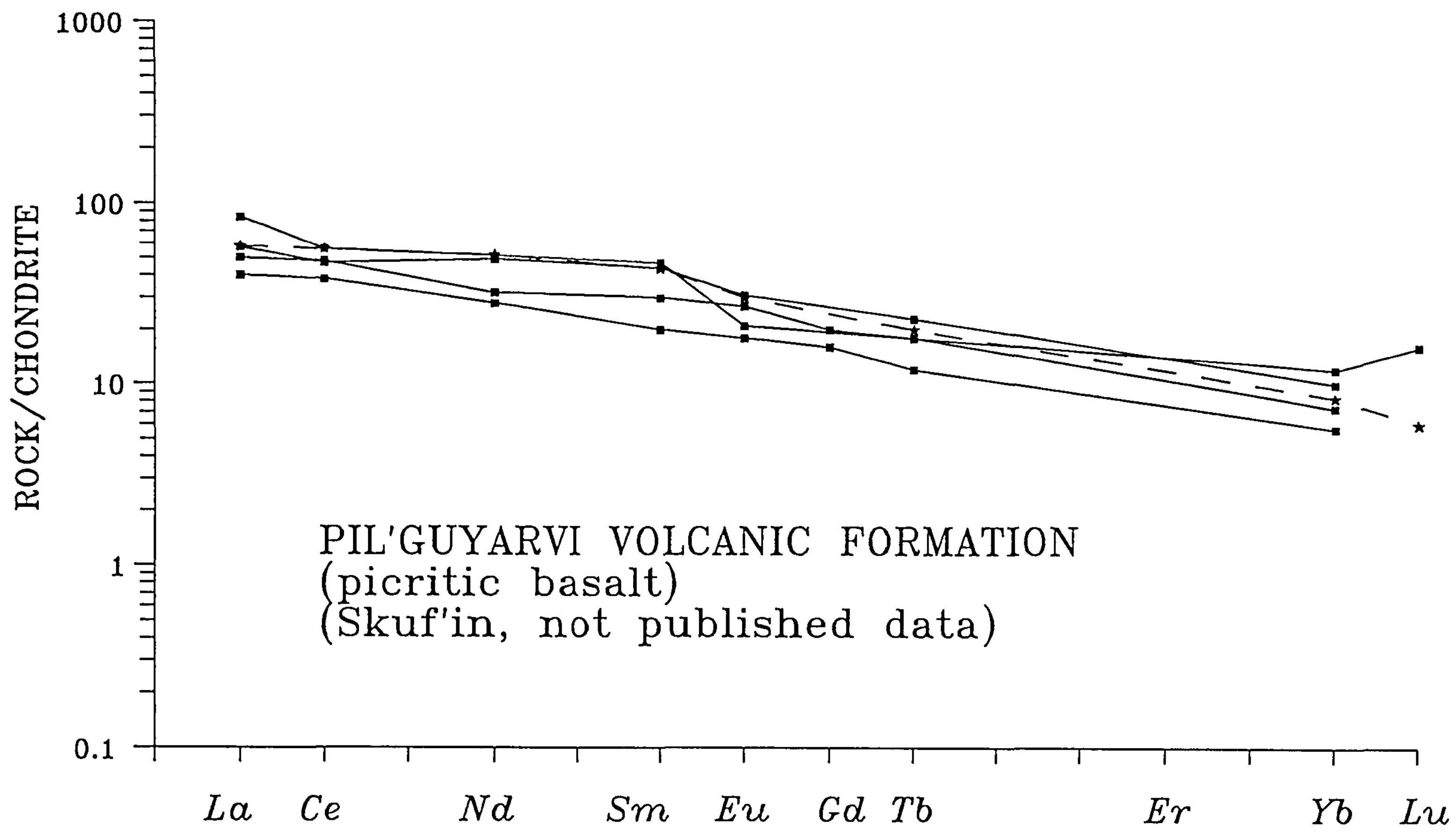

PIL'GUYARVI VOLCANIC FORMATION (ferropicrites)
(Hanski, Smol'kin, 1989)
ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
Ferropicrites of the cumulos zones
Globules of the globular ferropicrites
Matrix of the globular ferropicrites

Fig.26


ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
PIL'GUYARVI VOLCANIC FORMATION
(picritic basalt)
(Skuf'in, not published data)

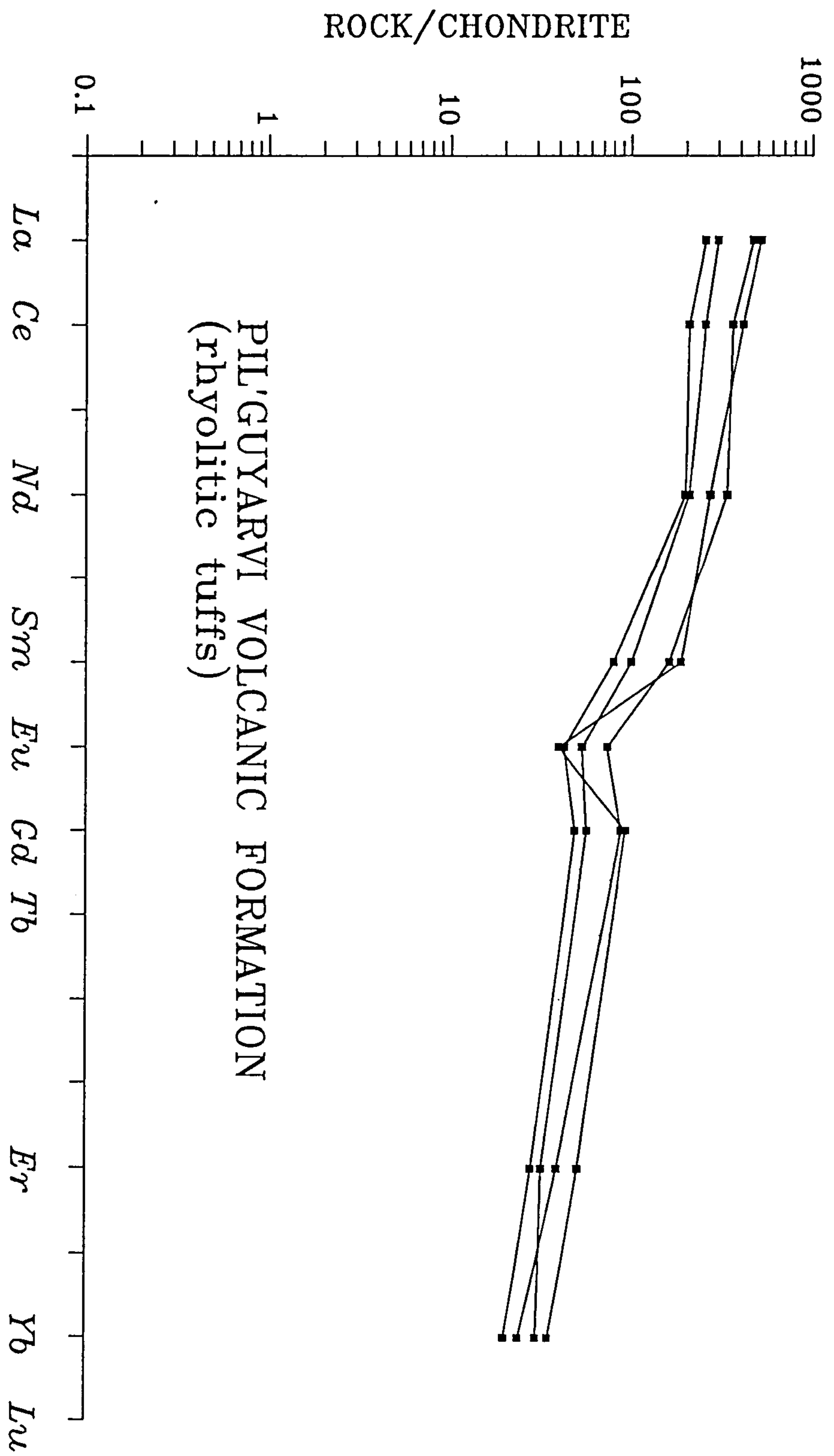
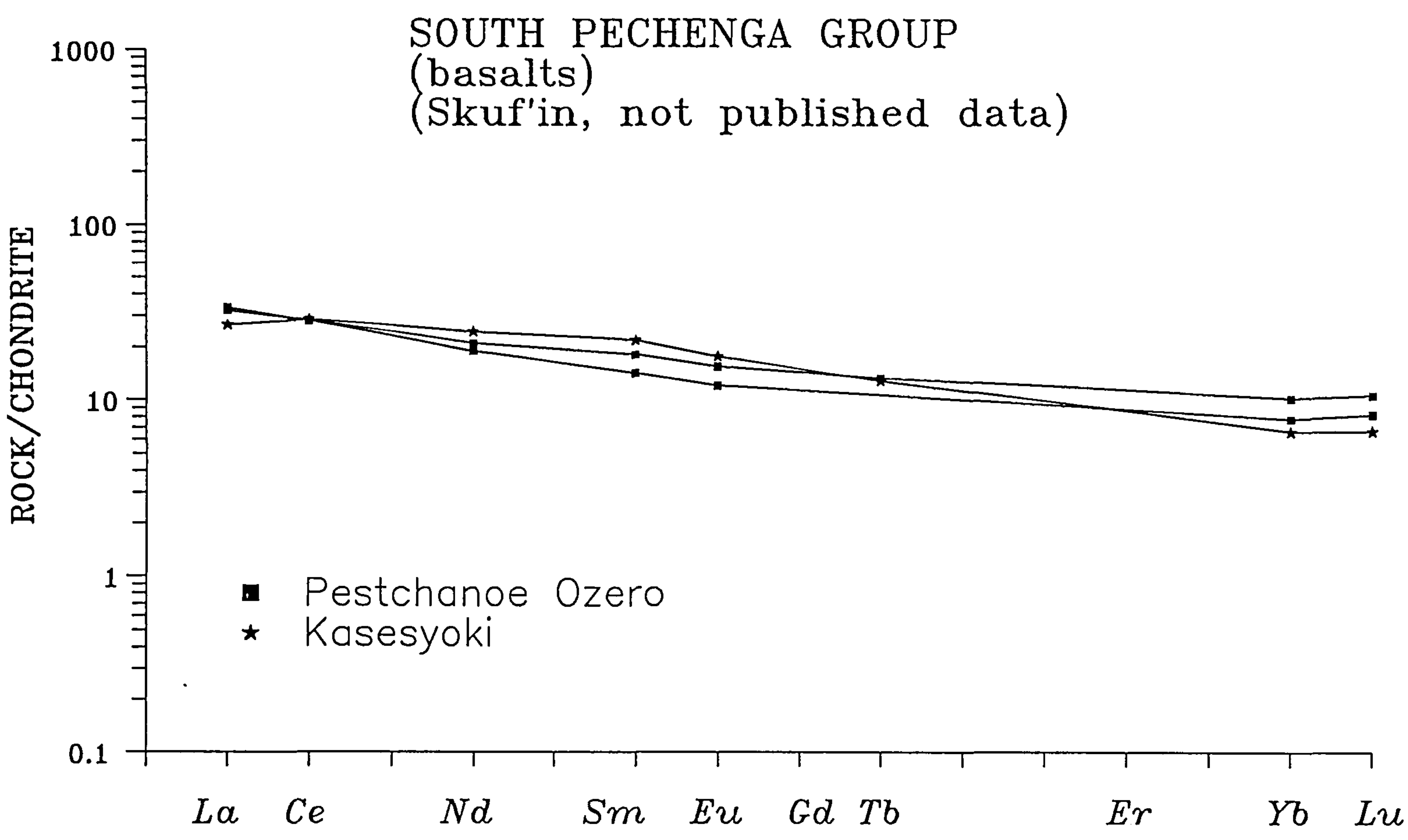
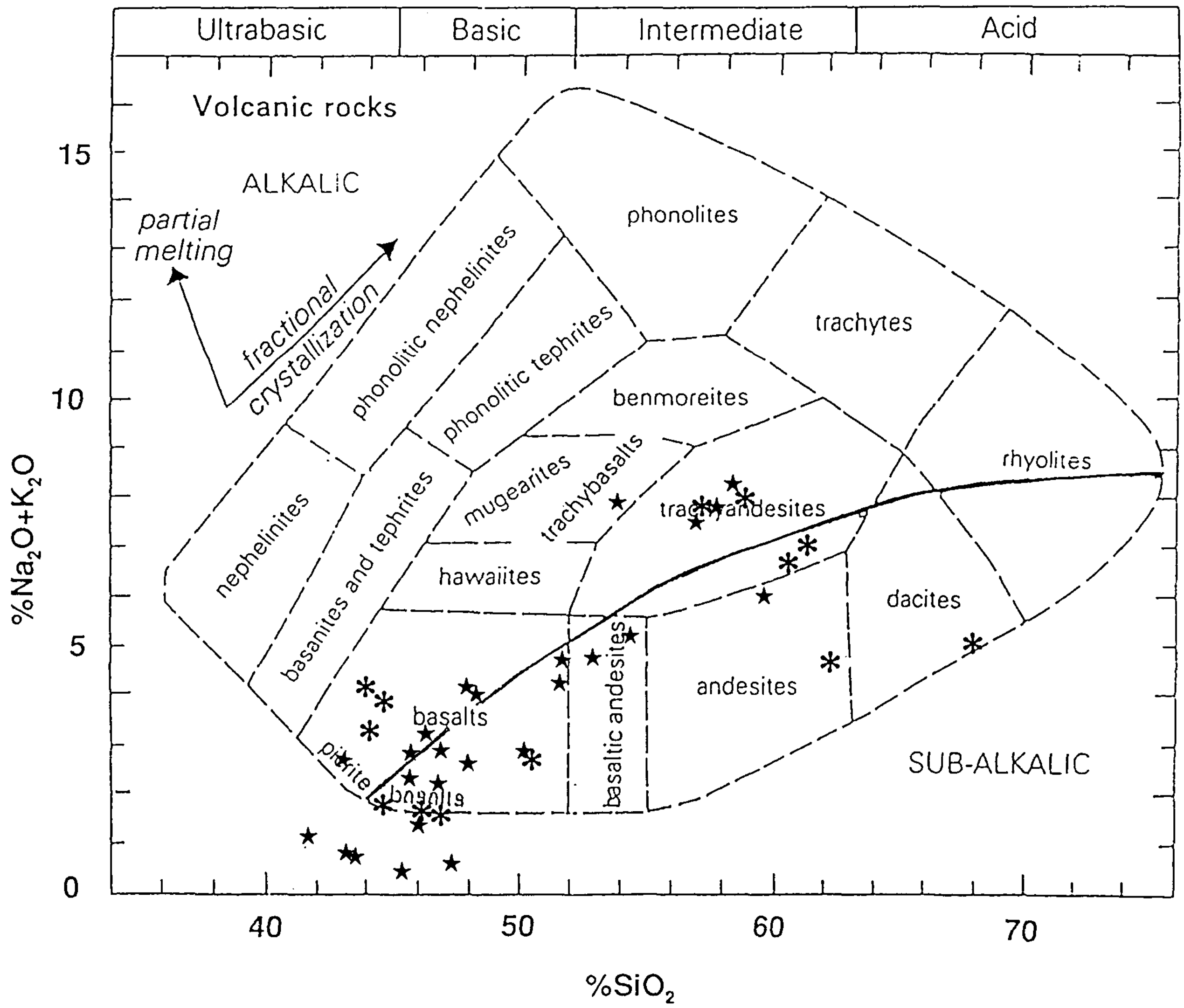

ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
PIL'GUYARVI VOLCANIC FORMATION
(rhyolitic tuffs)

Fig.27

Fig.28


SOUTH PECHENGA GROUP
(basalts)
(Skuf'in, not published data)
ROCK/CHONDRITE
1000
100
10
1
0.1
La Ce Nd Sm Eu Gd Tb Er Yb Lu
Pestchanoe Ozero
Kasesyoki

SOUTH PECHENGA AND LANGVANNET GROUPS



∗ Pechenga and Pasvik samples (this work)
★ Pechenga samples (Predovsky et al.1974)

Fig.29

Fig.30

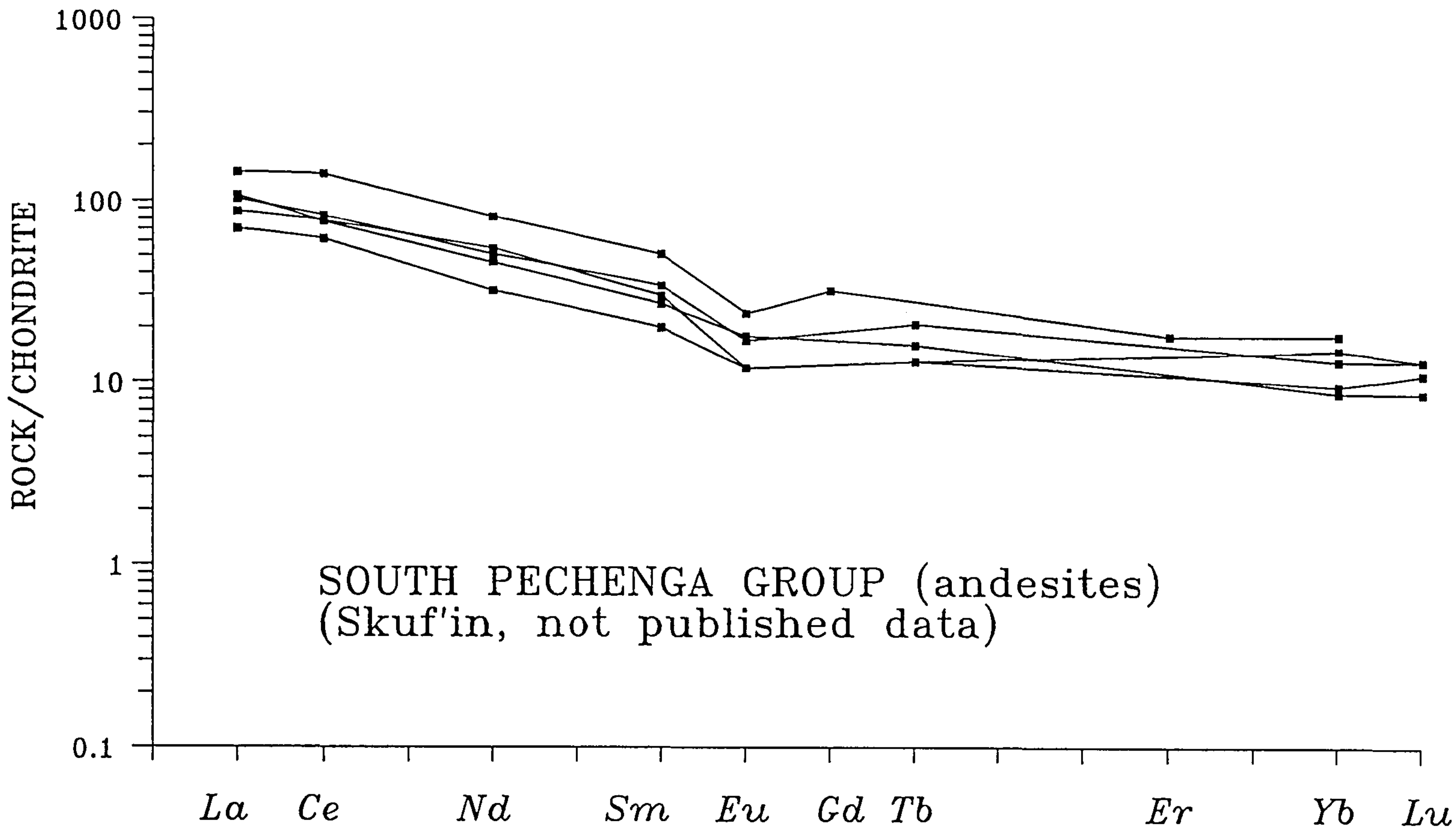

1000
100
10
1
0.1
ROCK/CHONDRITE
SOUTH PECHENGA GROUP (andesites)
(Skuf'in, not published data)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.31

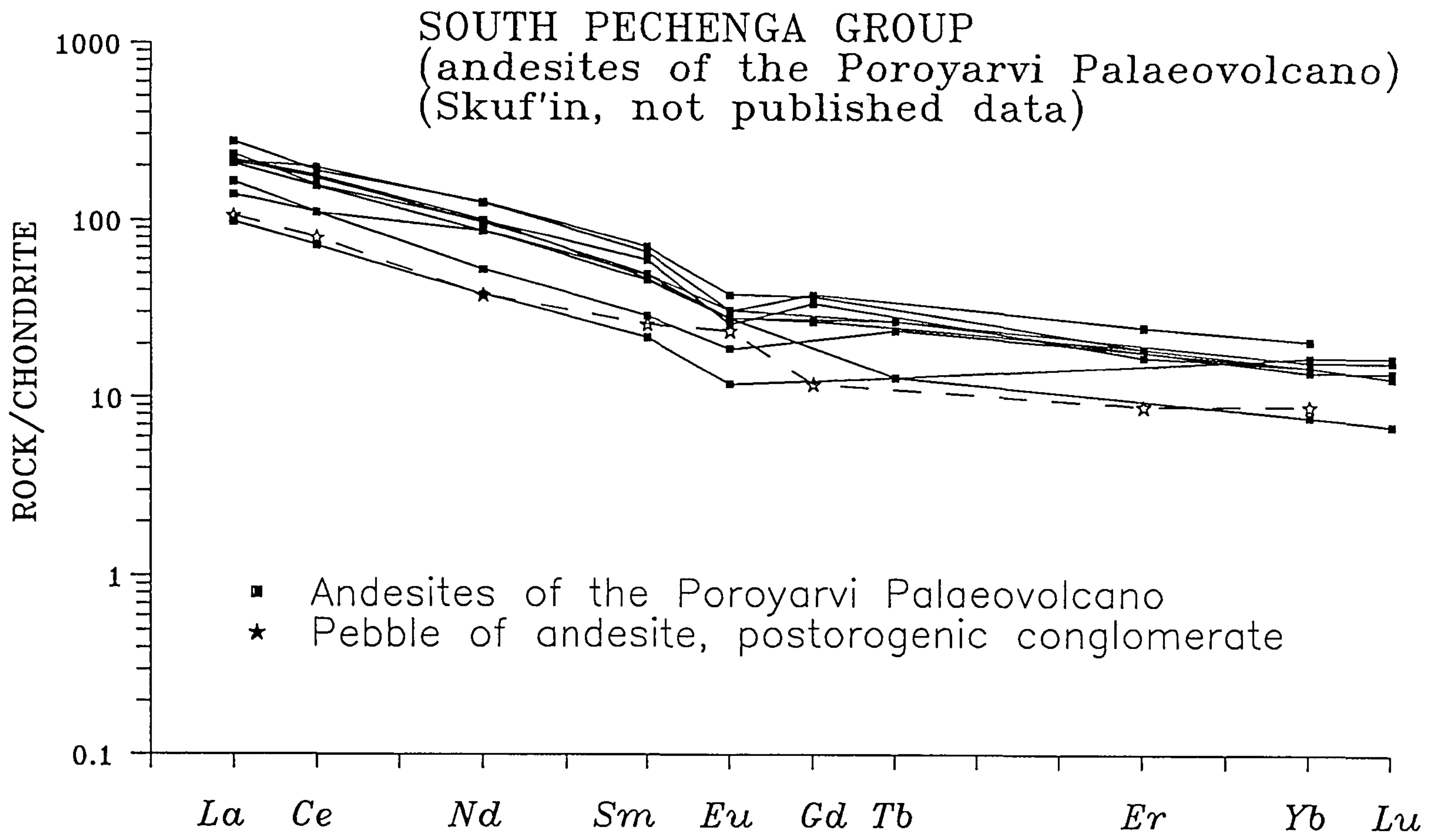
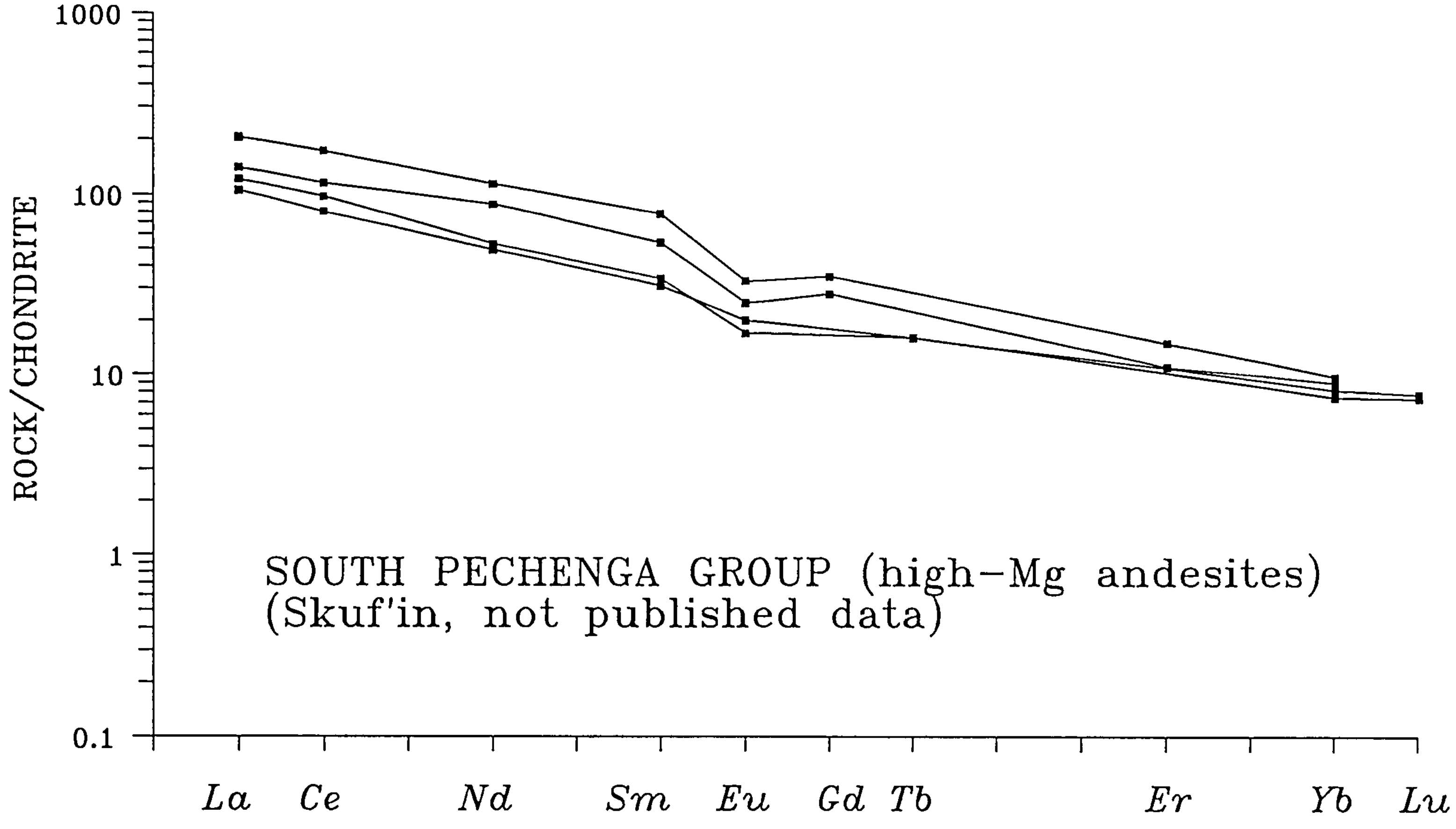

SOUTH PECHENGA GROUP
(andesites of the Poroyarvi Palaeovolcano)
(Skuf'in, not published data)
ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
Andesites of the Poroyarvi Palaeovolcano
Pebble of andesite, postorogenic conglomerate

Fig.32



ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
SOUTH PECHENGA GROUP (high-Mg andesites)
(Skuf'in, not published data)

Fig.33

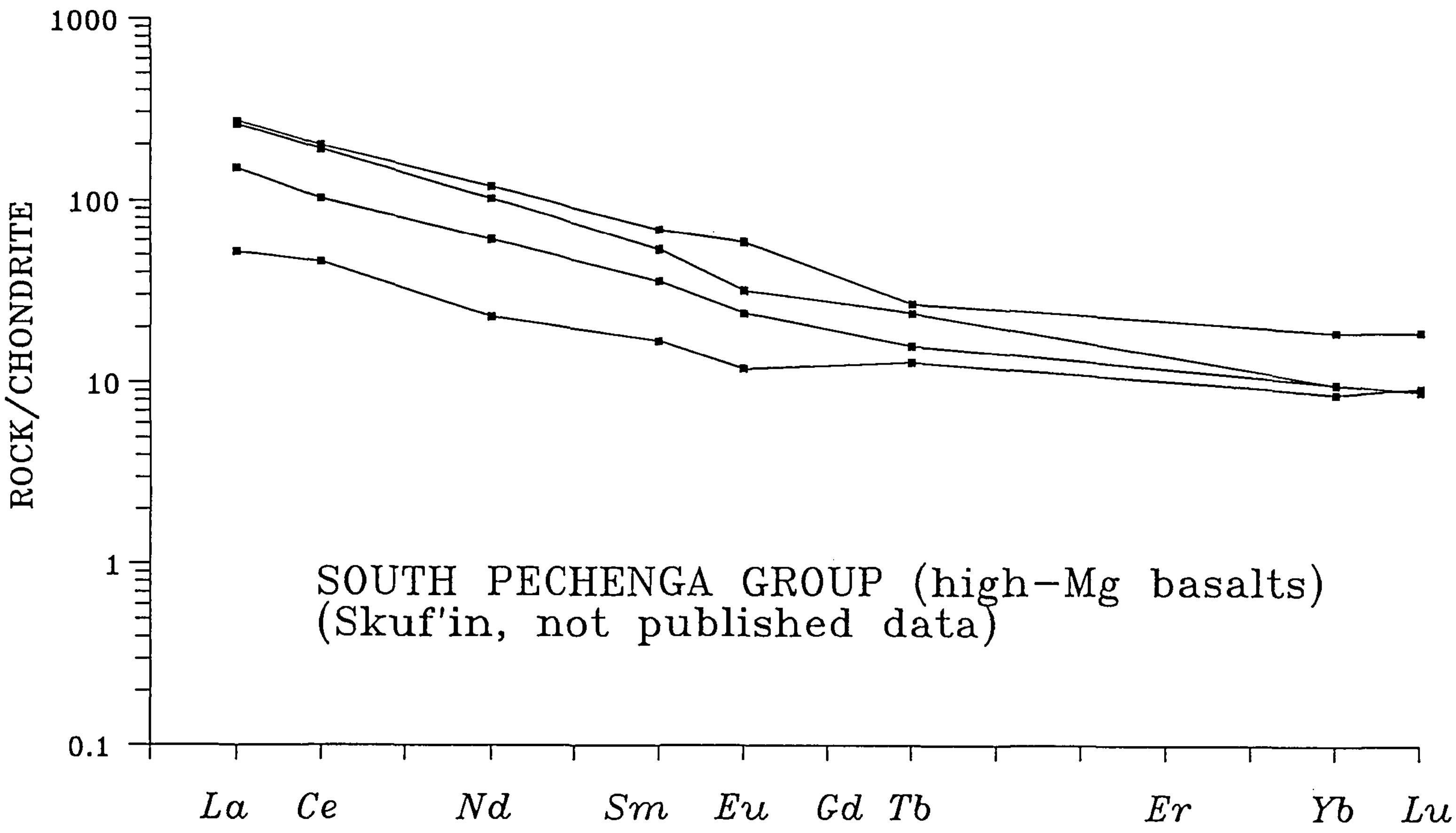
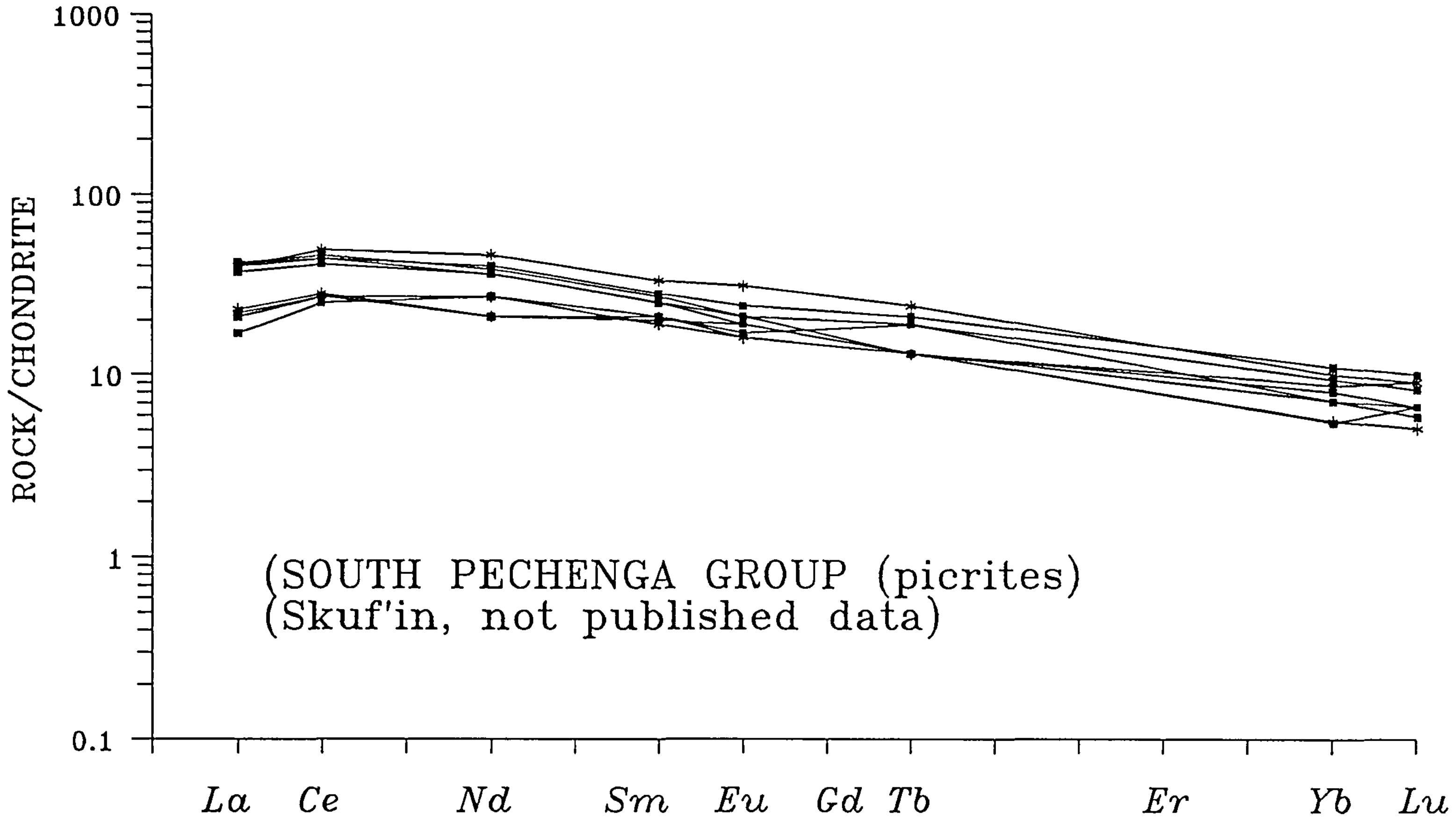
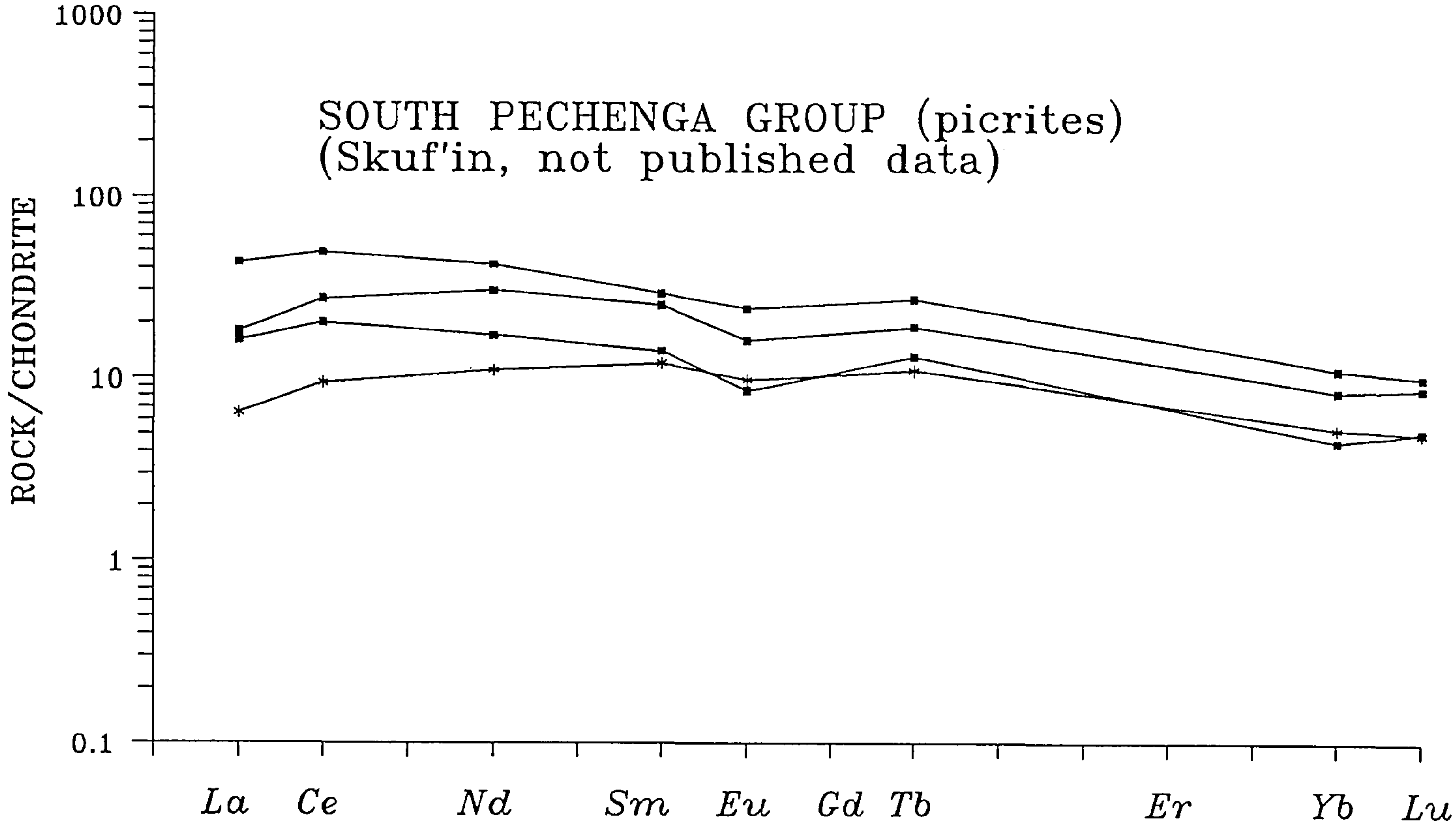

ROCK/CHONDRITE
1000
100
10
1
0.1
SOUTH PECHENGA GROUP (high-Mg basalts)
(Skuf'in, not published data)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.34



ROCK/CHONDRITE
1000
100
10
1
0.1
(SOUTH PECHENGA GROUP (picrites)
(Skuf'in, not published data)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.35


SOUTH PECHENGA GROUP (picrites)
(Skuf'in, not published data)
ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

THE DEPOSITION TIME OF THE PECHENGA-IMANDRA/VARZUGA SUPERGROUP

12 ANDESITE OF THE POR'ITASH SUBVOLCANIC INTRUSION

1778±15 Rb-Sr

---

11 ACID VOLCANIC OF THE TOMINGA GROUP

1870±71 Rb-Sr

---

10 ANDESITE OF THE SOUTH PECHENGA GROUP

1970±82 Rb-Sr

---

9 RHYOLITIC TUFFS

1970±5 U-Pb (ZIRCON)

---

8 FERROPICRITES

1955±43 Pb-Pb
1990±66 Sm-Nd

---

7 SULPHIDE Ni-Cu ORE

1870±50 Pb-Pb

---

6 GABBRO-WEHRLITE INTRUSIONS

1990±55 Pb-Pb
1960±66 Pb-Pb
1980±72 Rb-Sr
1980±150 Pb-Pb
1970±110 Sm-Nd

---

5 BASALTIC ANDESITE OF THE AKHMALAHTI FORMATION

2330±38 Rb-Sr

---

4 ACID VOLCANIC OF THE SEIDORECHKA FORMATION

2423±7 U-Pb (ZIRCON)

---

3 GABBRO-NORITE OF THE GORA GENERAL'SKAYA LAYERED INTRUSION

2453±42 Sm-Nd

---

2 GABBRO-NORITE OF THE IMANDRA LAPOLITH

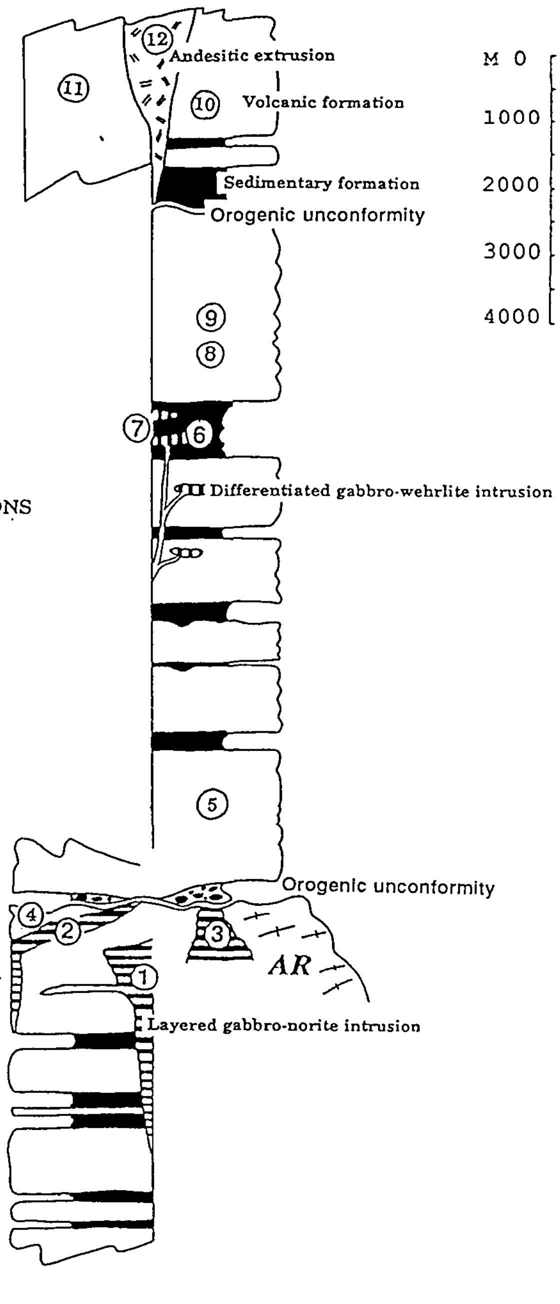
2444±77 Sm-Nd *
2396±7 U-Pb (ZIRCON) **

---

1 GABBRO-NORITE OF THE PANSKIE TUNDRY LAYERED INTRUSION

2487±51 Sm-Nd *
2471±4 U-Pb (ZIRCON) **

PECHENGA ZONE



IMANDRA-VARZUGA ZONE

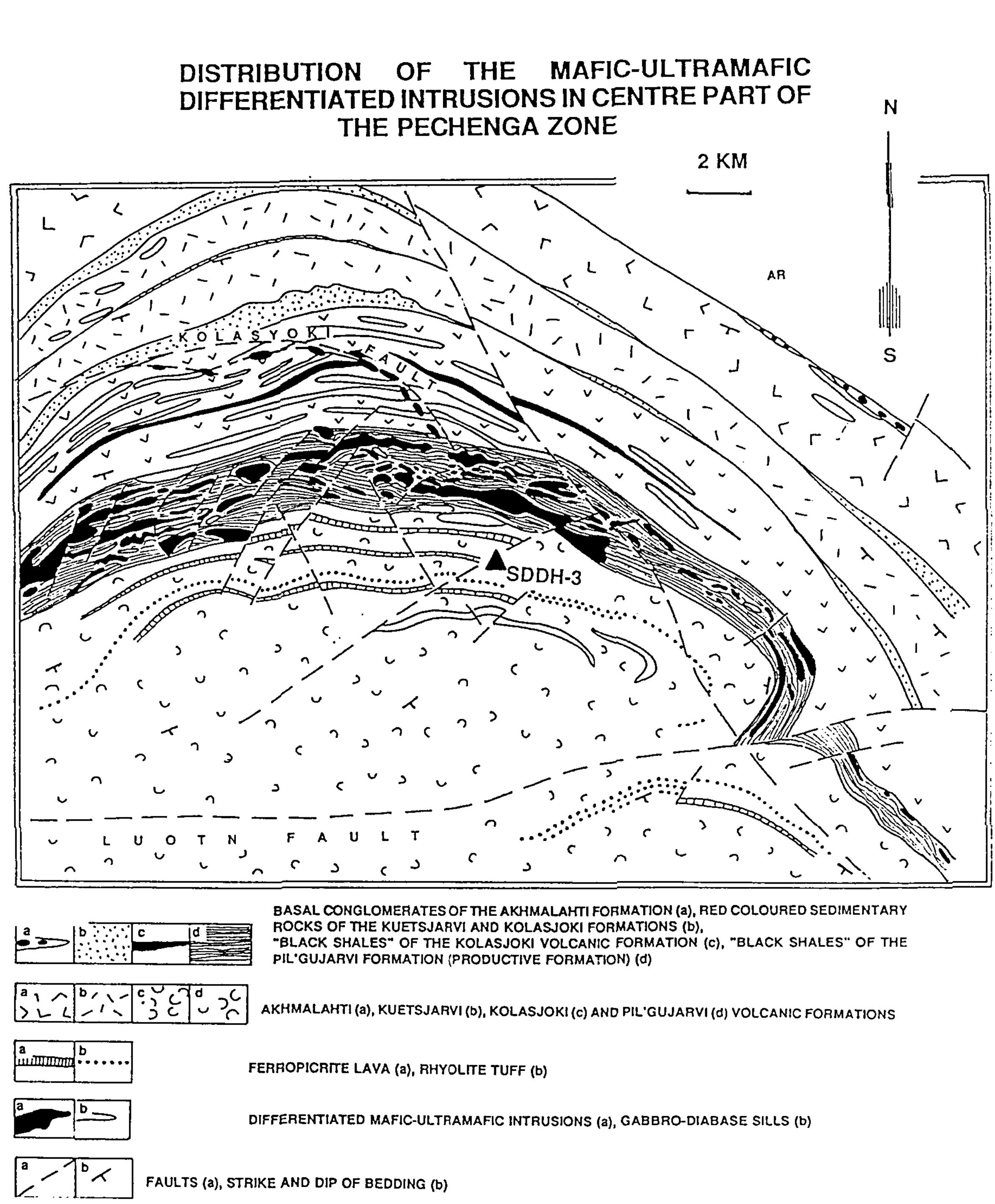
Fig.36

CAPTION

Fig.36 Radiometrical age determinations for the Pechenga and Imandra/Varzuga Supergroups.

Original data come from: (1*) Dokuchaeva et al. (1990); (1**, 2**, 4, 11) Mitrofanov et al. (1991); (2*) Balashov et al. (1990[1]); (3) Bakushkin et al. (1990);(5) Balashov et al. (1990[2]); (6, 7) Mitrofanov et al. (1990); (8, 9) Hanski et al. (1990); (10, 12) Skuf'in (personal communication, 1991)

DISTRIBUTION OF THE MAFIC-ULTRAMAFIC DIFFERENTIATED INTRUSIONS IN CENTRE PART OF THE PECHENGA ZONE



BASAL CONGLOMERATES OF THE AKHMALAHTI FORMATION (a), RED COLOURED SEDIMENTARY ROCKS OF THE KUETSJARVI AND KOLASJOKI FORMATIONS (b), "BLACK SHALES" OF THE KOLASJOKI VOLCANIC FORMATION (c), "BLACK SHALES" OF THE PIL'GUJARVI FORMATION (PRODUCTIVE FORMATION) (d)

AKHMALAHTI (a), KUETSJARVI (b), KOLASJOKI (c) AND PIL'GUJARVI (d) VOLCANIC FORMATIONS

FERROPICRITE LAVA (a), RHYOLITE TUFF (b)

DIFFERENTIATED MAFIC-ULTRAMAFIC INTRUSIONS (a), GABBRO-DIABASE SILLS (b)

FAULTS (a), STRIKE AND DIP OF BEDDING (b)

Fig.37

SYNSEDIMENTARY AND SYNVOLCANIC FAULTS OF THE PECHENGA ZONE

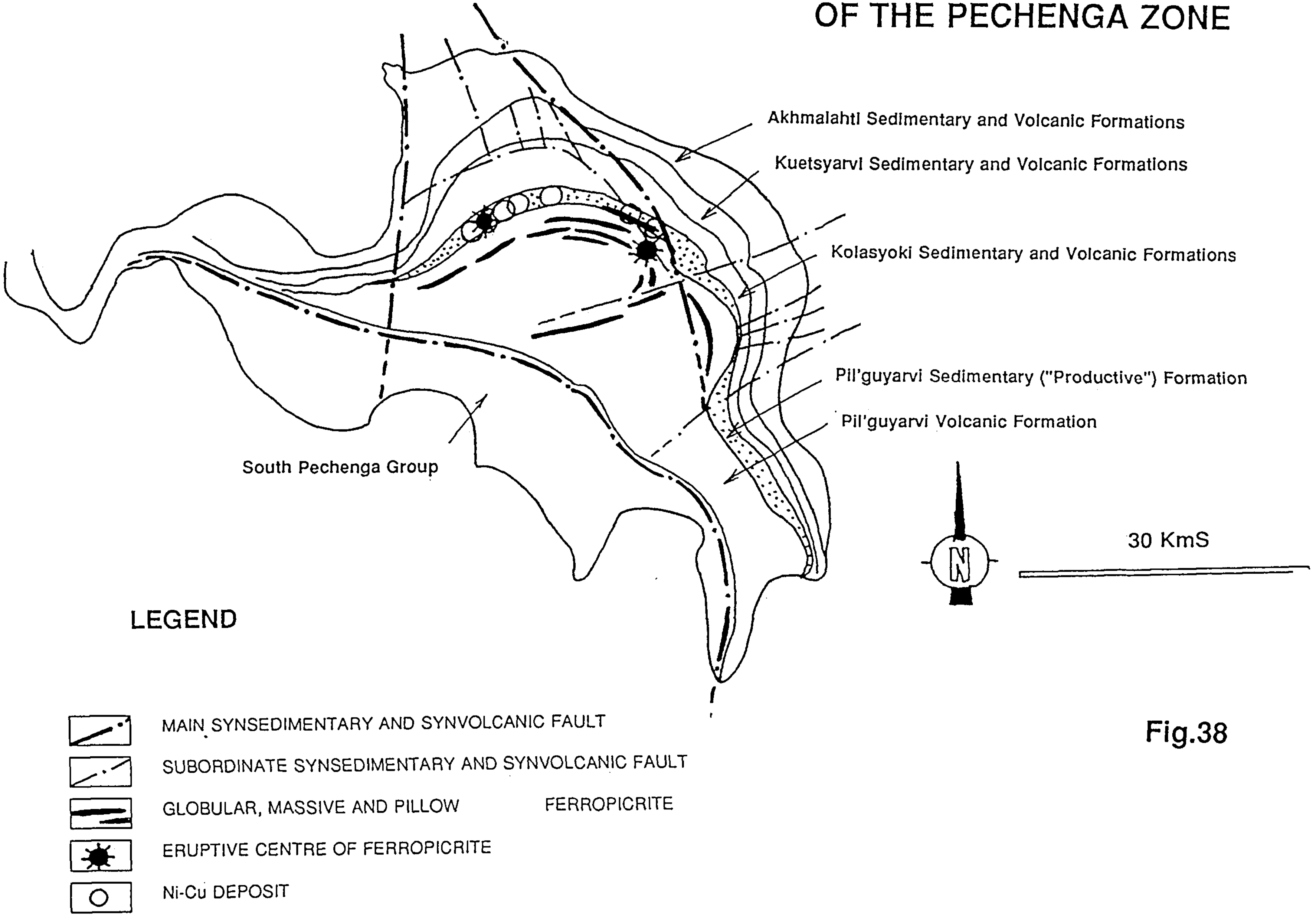
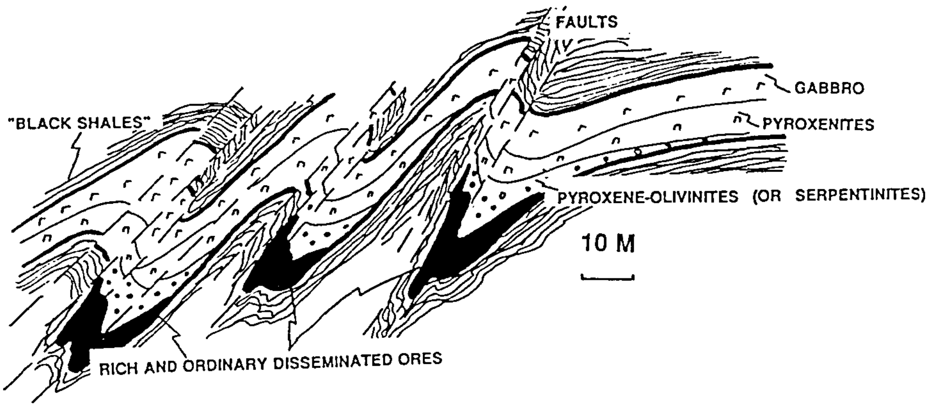


Fig.38

MAIN TYPES OF Ni-Cu ORES OF THE PECHENGA AREA (SIMPLIFIED SECTIONS)

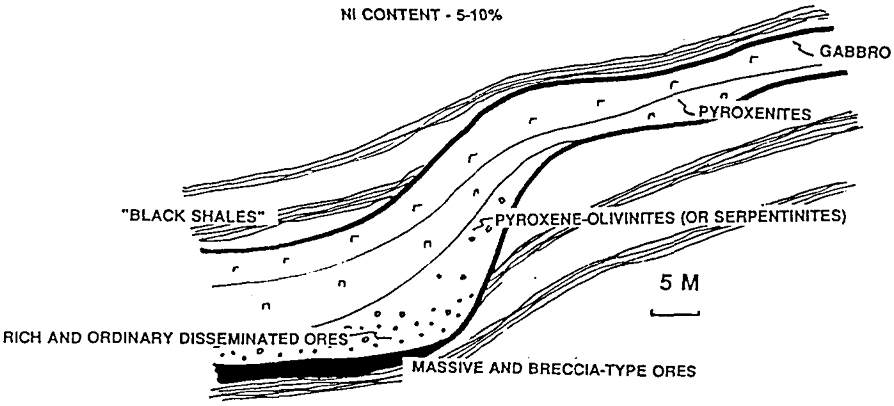
THE 1ST TYPE - MAGMATIC-METAMORPHIC-HYDROTHERMAL ORES

NI CONTENT - 0,8-3,0%



THE 2HD TYPE - MAGMATIC ORES

NI CONTENT - 5-10%



THE 3D TYPE - METAMORPHIC-HYDROTHERMAL ORES

NI CONTENT - O,8-5,0%

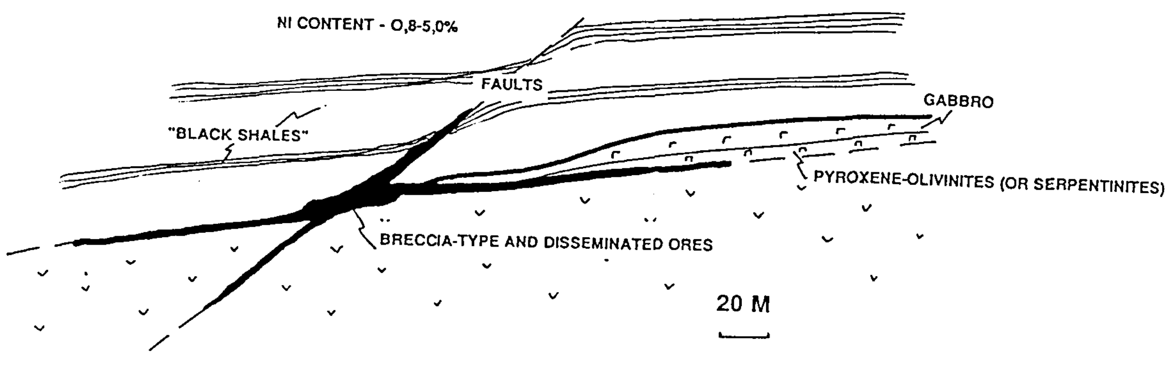


Fig.39

Fig.40

VERTICAL SECTIONS THROUGH THE EXPOSED SEQUENCE AT THE TYPE LOCALITIES AT BRATTLI (1) AND BJØRNBUGT (2, 3)

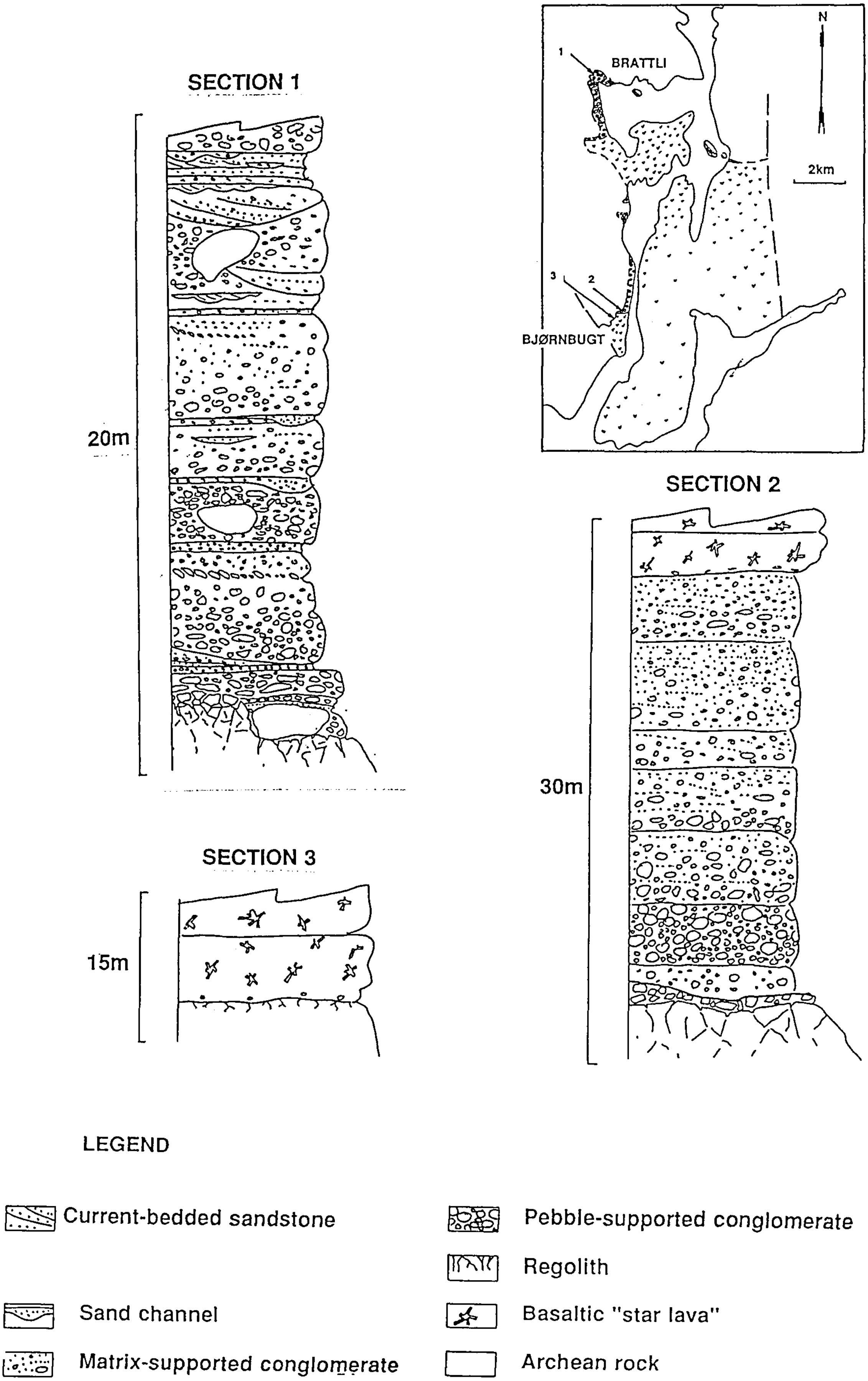


Fig.41

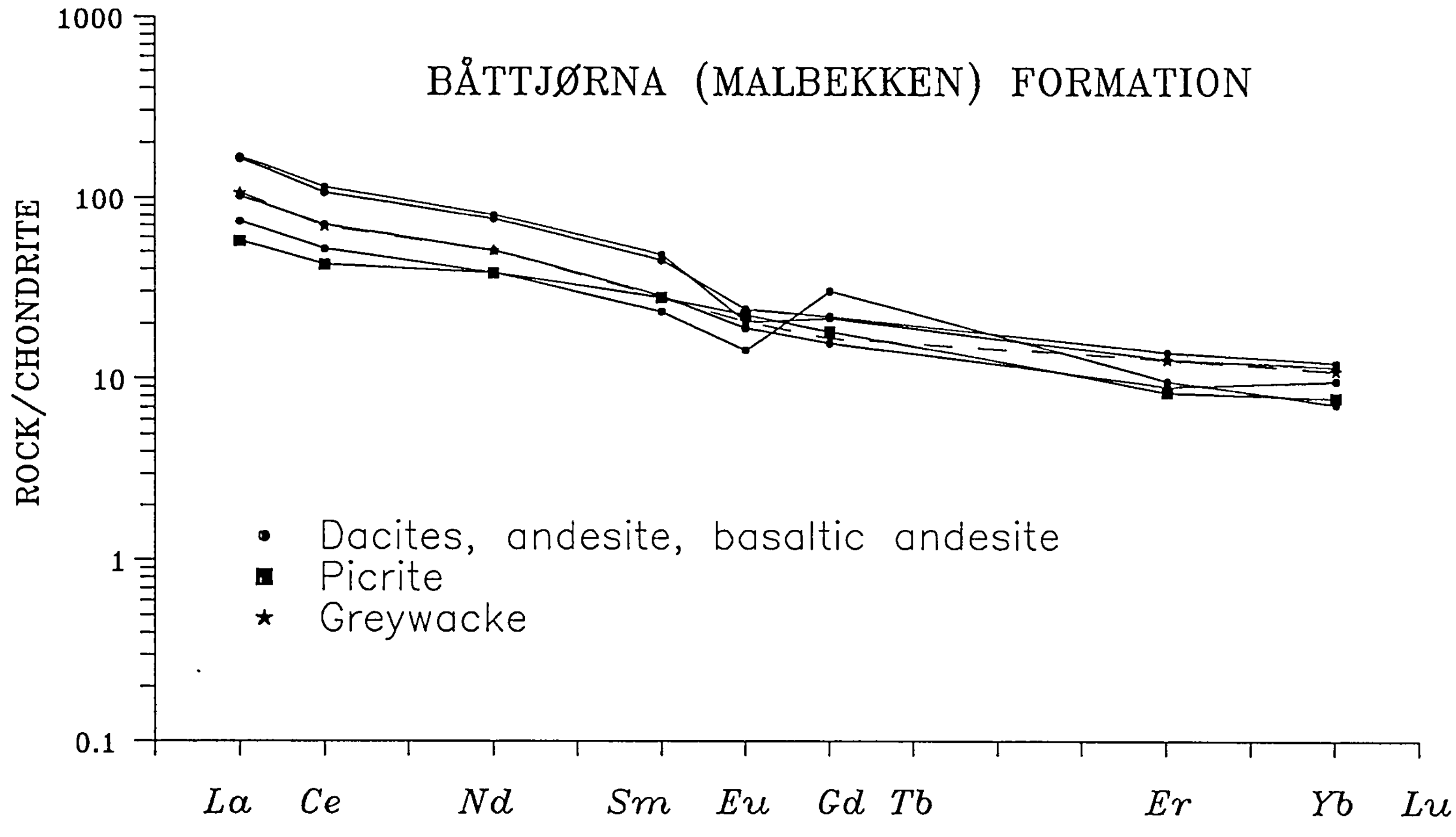
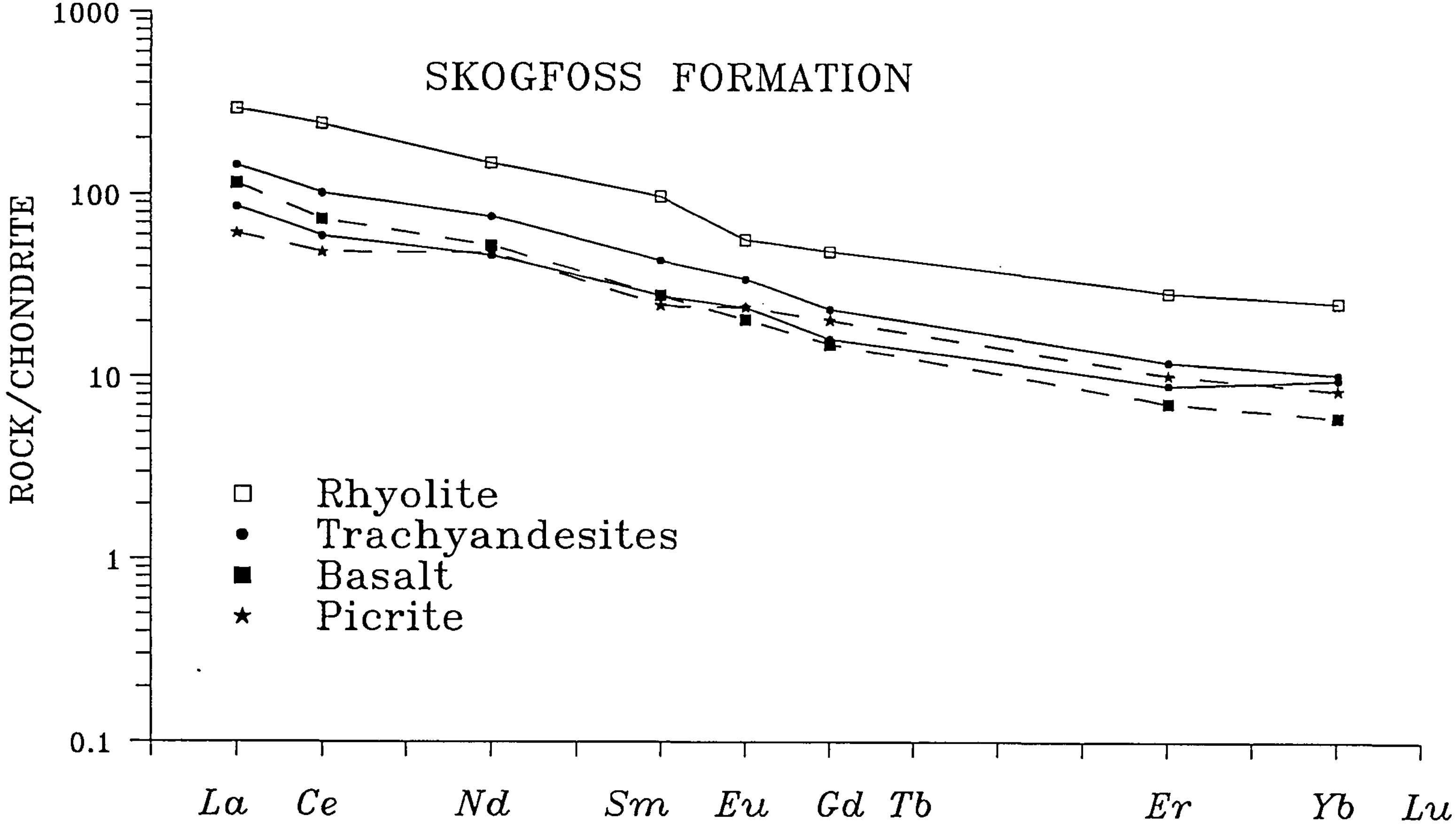

BÅTTJØRNA (MALBEKKEN) FORMATION
ROCK/CHONDRITE
1000
100
10
1
0.1
Dacites, andesite, basaltic andesite
Picrite
Greywacke
La Ce Nd Sm Eu Gd Tb Er Yb Lu

Fig.42


SKOGFOSS FORMATION
ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
Rhyolite
Trachyandesites
Basalt
Picrite

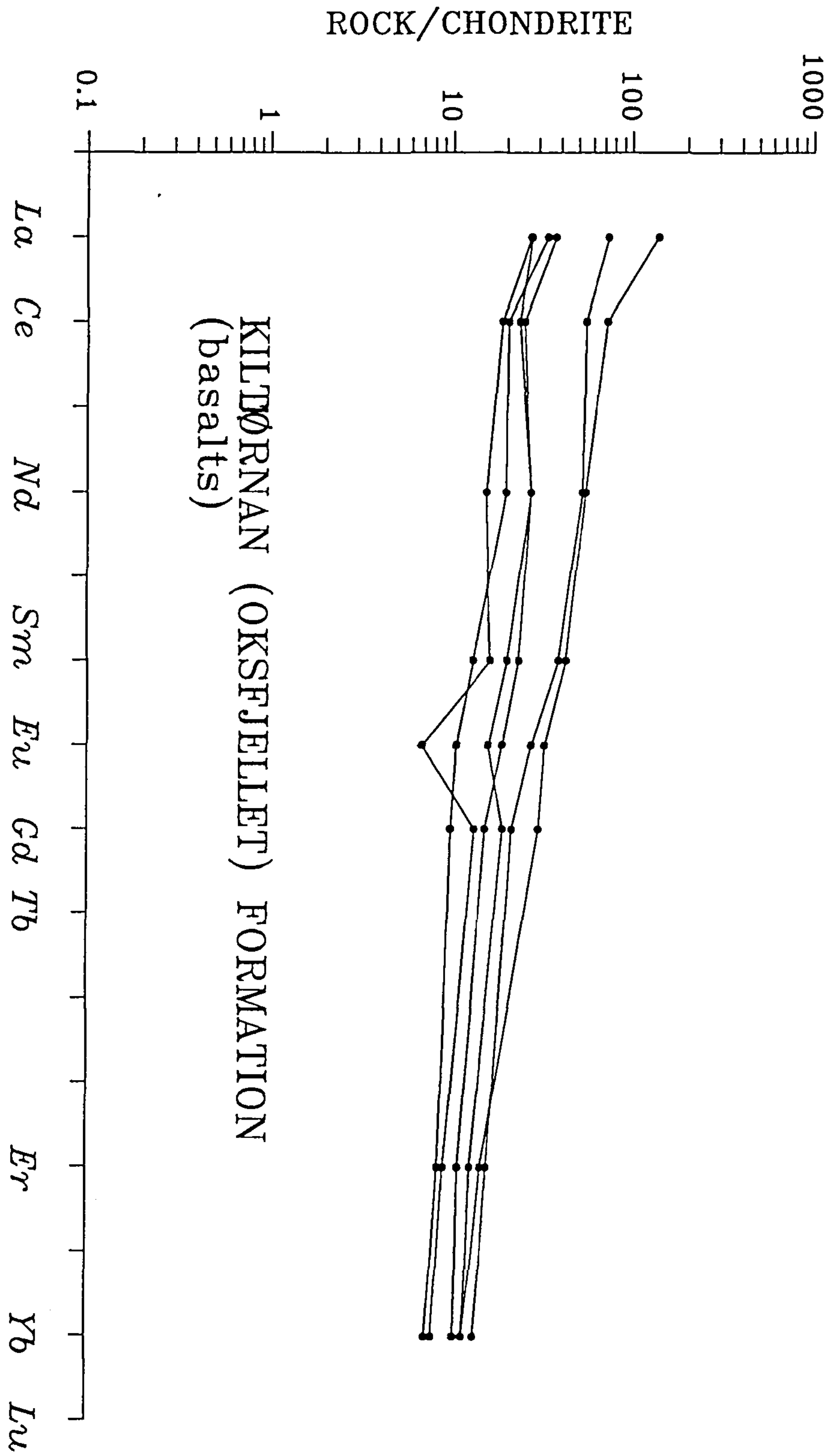

ROCK/CHONDRITE
1000
100
10
1
0.1
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu
KILTØRNAN (OKSFJELLET) FORMATION
(basalts)

Fig.43

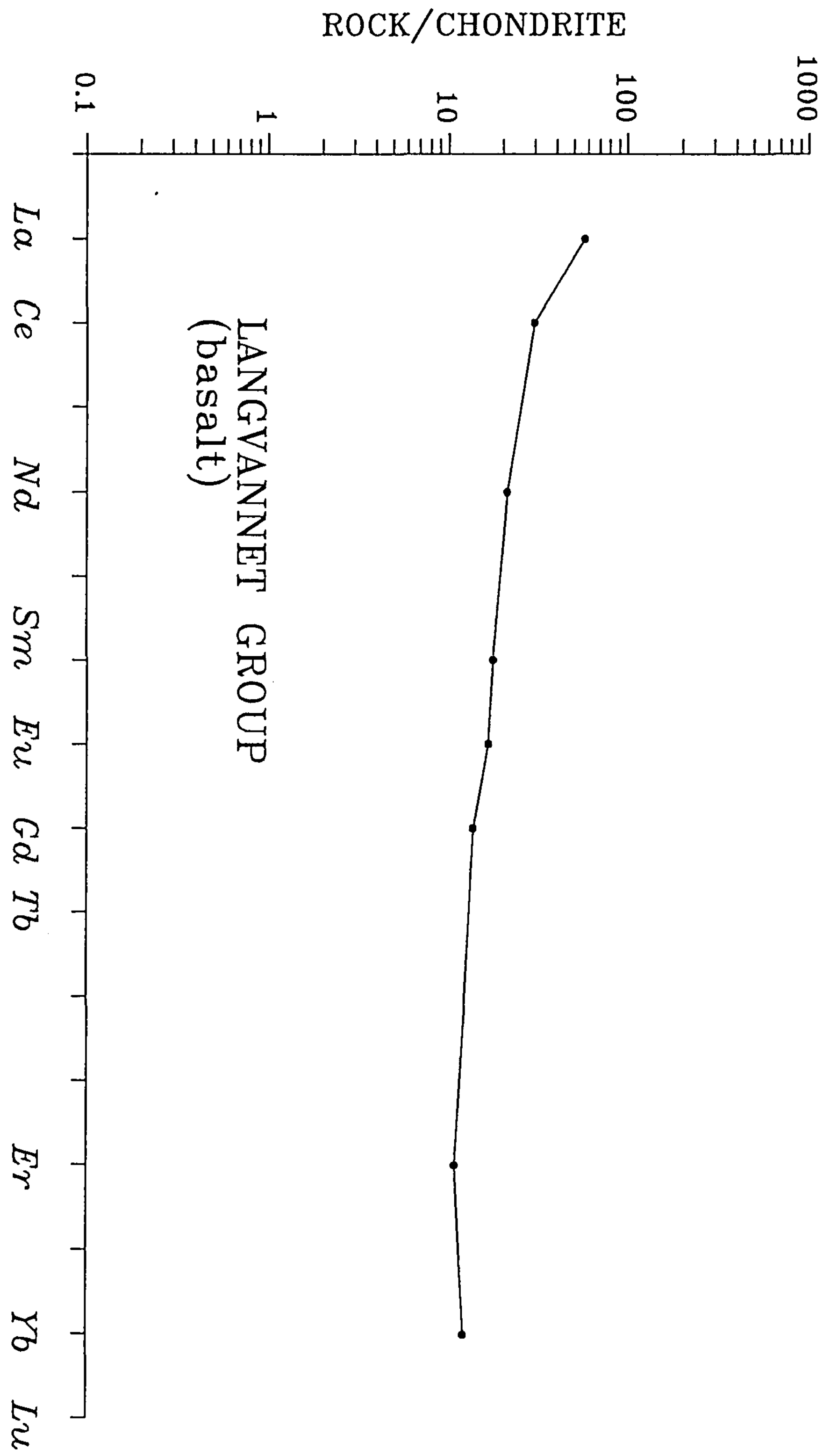

ROCK/CHONDRITE
0.1
1
10
100
1000
LANGVANNET GROUP
(basalt)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.44

Fig.45

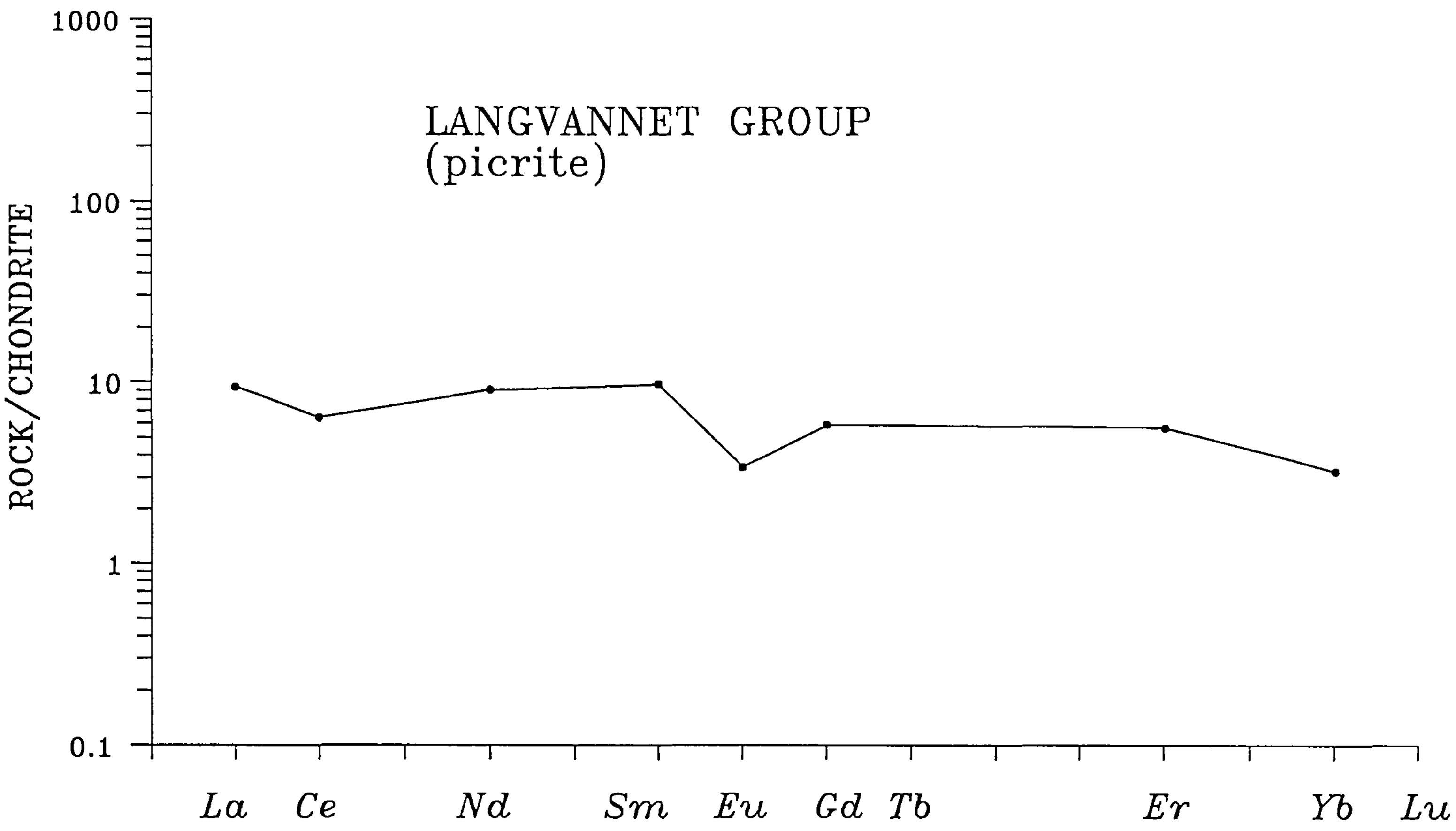

1000
100
10
1
0.1
ROCK/CHONDRITE
LANGVANNET GROUP
(picrite)
La
Ce
Nd
Sm
Eu
Gd
Tb
Er
Yb
Lu

Fig.46

CORRELATION OF THE "PRODUCTIVE" FORMATIONS OF THE PECHENGA AND PASVIK ZONES

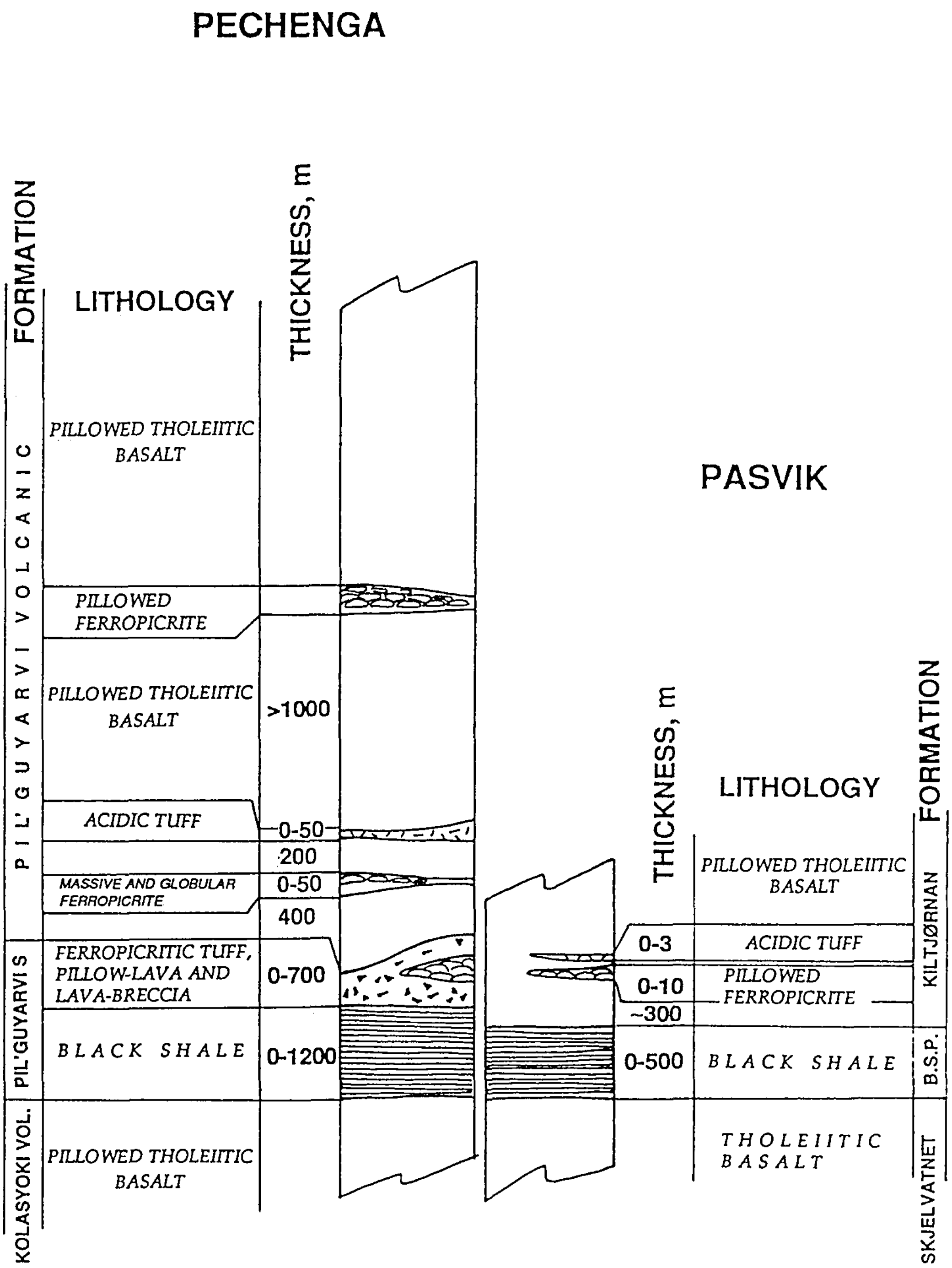


Table 1

Sulphur isotope values of pyrite and pyrrhotite of the Pil'fuyarvi Sedimentary Formation
(Melezhik & Grinenko, unpublished data)

Sample N	Locality	Stratigraphy and rock description	Type of sulphide	34S%
11a	Raysoayvi drill hole	Member C, middle part, ferropicritic tuff	Early diagenetic pyritic pyrrhotite concretion, rim	8.3
11b	"	"	" , mantle	7.3
11c	"	"	" , core	9.1
11d	"	"	" , mantle	7.7
11e	"	"	" , rim	9.3
			Small late diagenetic pyrrhotite inclusions and dissaminated pyrrhotite icluded in the late diagenetic carbonate concretions:	
535-1cr	Drill hole 2900	Member C, upper part, ferropicritic tuffite	pyrrhotite from core of carbonate concretion	6.2
535-2cr	"	"	"	8
535-1in	"	"	small pyrrhotite concretions from middle part of the carbonate concretion	7.1
535-2in	"	"	"	6.5
535-3in	"	"	"	6.7
535-4in	"	"	"	-3.3

535-5in	Drill hole 2900	Member C, upper part, ferropicritic tuffite	"	7.8
535-6in	"	"	"	7.7
535-7in	"	"	"	7.3
535-8in	"	"	"	3.8
535-9in	"	"	"	7.9
535-10in	"	"	"	7.9
535-11in	"	"	"	5.7
535-12in	"	"	"	3.9
535-13in	"	"	"	4.3
535-14in	"	"	"	6.6
535-15in	"	"	"	5.7
535-16in	"	"	"	6.5
535-17in	"	"	"	3.8
535-18in	"	"	"	7
535-19in	"	"	"	7.1
535-20in	"	"	"	3.7
535-21in	"	"	"	6.8
535-22in	"	"	"	5.4
535-23in	"	"	"	0.9
535-24in	"	"	"	7
535-25in	"	"	"	6.9
535-26in	"	"	"	6.3
535-27in	"	"	"	6.3
535-28in	"	"	"	2.1
535-29in	"	"	"	7.5
535-1rm	"	"	dissaminated pyrrhotite from rim of the carbonate concretion	7.5
535-2rm	"	"	"	7.3
535-3rm	"	"	"	6.6
535-5rm	"	"	"	5.7
535-6rm	"	"	"	6.3

535-7rm	Drill hole 2900	Member C, upper part, ferropicritic tuffite	"	7.2
34a	Kotsel'vaara quarry	Member C, lower part, ferropicritic tuff	Late diagenetic-catagenetic pyrite--pyrrhotite zonal concretion, pyritic core	12.4
34c	"	"	, pyrrhotite mantle	23.8
34d	"	"	, pyrrhotite mantle	8.4
35a	"	"	Late diagenetic--catagenetic pyrrhotite zonal concretion, core	7.1
35c	"	"	, mantle	8.3
35g	"	"	, rim	7.4
35h	"	"	, rim	7.6
35i	"	"	, core	8.2
35k	"	"	, core	8
35l	"	"	, core	8.5
35m	"	"	, rim	7.9
35n	"	"	, rim	7.5
36a	"	"	, rim	7.8
36b	"	"	, rim	8.1
36c	"	"	, rim	8.6
36d	"	"	, rim	8.9
36e	"	"	, rim	8.8
36f	"	"	, rim	8.4
36g	"	"	, rim	8.3
36h	"	"	, rim	8.1
36i	"	"	, rim	8.6
36j	"	"	, rim	7.6
36k	"	"	, rim	7.8
36l	"	"	, mantle	9.4

36m	Kotsel'vaara quarry	Member C, lower part, ferropicritic tuff	, mantle	8.1
36n	"	"	, core	8.7
36o	"	"	, core	8.4
36p	"	"	, core	8.9
36q	"	"	, core	7.4
37a	"	"	Late diagenetic- -catagenetic pyrrhotite- -chalcopyrite concretion, pyrrhotite-chalcopyrite core	8
37b	"	"	"	8.8
37c	"	"	"	7.8
37d	"	"	"	8.2
37e	"	"	"	7.4
37f	"	"	"	7.8
37g	"	"	, pyrrhotite mantle	7.9
37h	"	"	, pyrrhotite mantle	8.4
37i	"	"	, pyrrhotite- -chalcopyrite core	7.4
37j	"	"	, pyrrhotite core	8
37k	"	"	, pyrrhotite core	9.3
37l	"	"	, pyrrhotite core	7.8
37n	"	"	, pyrrhotite core	8
37o	"	"	, pyrrhotite core	7.7
37p	"	"	, pyrrhotite mantle	6
37q	"	"	, pyrrhotite rim	8.4
38a	"	"	, pyrrhotite rim	8.6
38b	"	"	, pyrrhotite rim	9.9
38c	"	"	, pyrrhotite rim	8.8
38d	"	"	, pyrrhotite rim	8.2
38e	"	"	, pyrrhotite rim	8
38f	"	"	, pyrrhotite rim	12.1

38g	Kotsel'vaara quarry	Member C, lower part, ferropicritic tuff	, pyrrhotite rim	7.9
38h	"	"	, pyrrhotite rim	8
38i	"	"	, pyrrhotite rim	8.3
38j	"	"	, pyrrhotite rim	8.4
38k	"	"	, pyrrhotite rim	7.5
38l	"	"	, pyrrhotite rim	8.2
38m	"	"	, pyrrhotite rim	8.1
38n	"	"	, pyrrhotite rim	7.8
38o	"	"	, pyrrhotite rim	8.4
38p	"	"	, pyrrhotite rim	8.1
38q	"	"	, pyrrhotite rim	7.8
38r	"	"	, pyrrhotite rim	8.4
39a	"	"	Late diagenetic- -catagenetic pyrrhotite layer	22.5
39b	"	"	"	20.1
39c	"	"	"	23.2
39d	"	"	"	19.5
39e	"	"	"	22.2
39f	"	"	"	19.3
39g	"	"	"	18
39h	"	"	"	18.7
23a	Drill hole 2905	Member B, upper part, silt- and mudstone	Sedimentary pyritic layer of framboidal pyrite, layer 1*****	-1.1
23b	"	"	"	-1.2
23c	"	"	"	-2.5
23d	"	"	"	-1.9
23e	"	"	"	-0.9
23g	"	"	"	-2.2
23h	"	"	"	-1.8
24a	"	"	layer 2*****	-1.1

24b	Drill hole 2905	Member B, upper part, silt- and mudstone	, layer 2*****	-0.5
24c	"	"	"	-0.5
24d	"	"	"	0.3
1a	Pil'guyarvi quarry	"	Early diagenetic pyritic concretion, rim	-2.1
1b	"	"	" , rim	-1.4
2a	"	"	" , rim	-0.6
2b	"	"	" , core	-0.6
2c	"	"	" , rim	-0.5
3a	"	"	Early diagenetic zonal pyritic concretion, core	-1.3
3b	"	"	" , rim	-1.3
4	"	"	" , core	-0.8
6b	"	"	" , rim	-0.8
	"	"		
7a	"	"	Early diagenetic zonal pyritic concretion with radial structure, core	-2.1
7b	"	"	" , mantle	-1.6
8a	"	"	" , core	-1.9
8c	"	"	" , mantle	-0.9
9a	"	"	Early diagenetic zonal pyritic concretion with radial structure and pyrrhotite outrim , outrim	-1
9b	"	"	" core	-1
40	Pil'guyarvi quarry	"	Early diagenetic zonal pyritic concretion with radial structure, core	-1.9
41a	"	"	, core	-1.4
41b	"	"	, core	-1
41c	"	"	, core	-1.9

43	Pil'guyarvi quarry	Member B, upper part, silt- and mudstone	, core	-0.3
44a	"	"	, core	-0.8
44b	"	"	, core	-2.7
44d	"	"	, outcore	-1.6
44e	"	"	, outcore	-0.4
45a	"	"	Early diagenetic non-zonal pyritic concretion, rim	-1.4
46a	"	"	, mantle	-0.9
46b	"	"	, mantle	-0.9
46c	"	"	, rim	-0.8
46d	"	"	, mantle	-1.1
46e	"	"	, mantle	-0.3
47a	"	"	, rim	-2.1
47b	"	"	, mantle	-2.1
47c	"	"	, mantle	-1
47d	"	"	, rim	-1.9
			Early diagenetic zonal pyritic concretion with radial structure and pyrrhotite outrim	
48a	"	"	, core	2
48b	"	"	, mantle	1
48c	"	"	, mantle	3.2
48d	"	"	, outrim	2.5
48e	"	"	, outrim	2.4
13a	Pil'guyarvi quarry	"	Early diagenetic zonal pyritic concretion with radial structure, core	3.8
13b	"	"	" , outcore	2.2
13c	"	"	" , mantle	2.6
13d	"	"	" , mantle	2

			Early diagenetic zonal pyritic concretion with radial structure and pyrrhotite outrim	
14a	Pil'guyarvi quarry	Member B, upper part, silt- and mudstone	" , core	2.9
14b	"	"	" , outcore	2.3
14c	"	"	" , outcore	2.5
14d	"	"	" , outrim	1.6
14e	"	"	" , outrim	2.5
14f	"	"	" , outrim	2.5
15a	"	"	" , outcore	2.7
15b	"	"	" , mantle	3.1
15c	"	"	" , outrim	2.1
16a	"	"	" , outcore	2.2
16b	"	"	" , mantle	3
16c	"	"	" , outcore	2.5
16d	"	"	" , outrim	1
16e	"	"	" , mantle	3.1
16f	"	"	" , outrim	2.7
16g	"	"	" , core	2.5
16h	"	"	" , mantle	2.5
16i	"	"	" , outrim	2.6
16j	"	"	" , mantle	2.4
17a	"	"	" , core	2.7
17b	"	"	" , mantle	2.6
17c	"	"	" , mantle	2.7
17d	"	"	" , mantle	2
18a	"	"	" , outcore	2.4
18b	"	"	" , mantle	2.4
18c	"	"	" , mantle	2.3
18d	"	"	" , outrim	1.3
19b	"	"	" , mantle	2.4

19c	Pil'guyarvi quarry	Member B, upper part, silt- and mudstone	" , mantle	2.6
20a	"	"	Interconcretional pyrrhotite of host rock	1.9
20b	"	"	"	1.7
21	"	"	"	2.3
22a	"	"	Early diagenetic zonal pyritic concretion with radial structure and pyrrhotite outrim " , core	2.7
22b	"	"	" , mantle	2.5
22c	"	"	" , mantle	2.1
22d	"	"	" , outrim	2
60a	Drill hole 2700	"	Diagenetic pyritic lens, bottom********	-2.5
60b	"	"	, bottom	-4.1
60c	"	"	, middle part	-1
60d	"	"	, middle part	9.6
60e	"	"	, top	11.8
60f	"	"	, top	12.4
60g	"	"	Diagenetic pyritic layer, bottom********	0
60h	"	"	, middle part	-0.01
60j	"	"	Thin diagenetic pyritic lens********	-3.1
60k	"	"	Diagenetic dissaminated pyrite from siltstone********	2
60l	"	"	"	2.6
60m	Drill hole 2700	Member B, upper part, silt- and mudstone	Thin diagenetic pyritic lens	-5.7

61a	"	"	Diagenetic pyritic lens, bottom********	-8.3
61b	"	"	, top	-2.3
61c	"	"	, bottom	-3.2
61d	"	"	, top	-2.5
61e	"	"	, bottom	-4.1
61f	"	"	, middle part	-3.1
61g	"	"	, middle part	2.4
61h	"	"	, top	12.8
62a	"	"	Diagenetic dissaminated pyrite from siltstone********	-1.4
62b	"	"	Diagenetic pyritic lens, bottom********	-5.5
62c	"	"	, middle part	-3.2
62d	"	"	, middle part	-1.8
62f	"	"	, top	-3.1
33a	Drill hole 2794	"	Large early diagenetic pyrite-pyrrhotite concretion recrystalized during the metamorphic stage, rim******	9.3
33b	"	"	, mantle	9.2
33c	"	"	, mantle	10.8
33d	"	"	, core	8.9
33e	"	"	, mantle	13.8
33f	"	"	, mantle	9
33g	"	"	, rim	8.5
33j	"	"	, rim	7.8
33k	"	"	, rim	9.3
10a	"	"	Late diagenetic pyritic layer, bottom	-3.4

10b	Drill hole 2794	Member B, upper part, silt- and mudstone	, centre	-3.9
10c	"	"	, top	-5.6
10d	"	"	, centre	2.5
10e	"	"	, centre	-7.4
50a	Drill hole 2400	"	Late diagenetic pyritic layer, bottom ***	8.9
50b	"	"	, middle part	5.8
50c	"	"	, middle part	12.4
50d	"	"	, middle part	8.1
50e	"	"	, top	9.3
51a	"	"	, bottom	9.3
51b	"	"	, middle part	7.2
51c	"	"	, middle part	10.3
51d	"	"	, middle part	7.7
51e	"	"	, top	8.8
12a	Drill hole 2400	"	Late diagenetic pyritic concretion, core	13
12c	"	"	" , core	13.5
12d	"	"	" , rim	14.2
12f	"	"	Late diagenetic brecciated pyritic concretion, rim	23.4
12g	"	"	" , rim	24.9
12h	"	"	Late diagenetic pyritic layer	10
12i	"	"	Late diagenetic pyritic concretion, rim	11.4

LITHOSTRATIGRAPHY AND CORRELATION OF THE SEDIMENTARY-VOLCANIC FORMATIONS OF THE PASVIK AND PECHENGA ZONES

LEGEND

1. QUARTZ-SERICITE GNEISS, PARTLY MYLONITIC
2. POLYCOMPONENT GNEISSES, PARTLY MYLONITIC
3. SANDSTONE WITH THIN BANDS OF SILTSTONE
4. PHYLITE AND SILTSTONE WITH SOME GREENSTONE AND GREENSCHIST
5. PILLOW-LAVA, MASSIVE GREENSTONE AND GREENSCHIST WITH ULTRAMAFIC CONGLOMERATE AND BANDS OF QUARTZITE
6. ANDESITE AND ANDESITIC VOLCANOCLASTIC SEDIMENTARY ROCK; PICRITIC AND PROBABLY KOMATIITIC PILLOW-LAVA AND LAVA-BRECCIA WITH VOLCANOCLASTIC PICRITIC CONGLOMERATE TO SILTSTONE; BASALT
7. THOLEIITIC PILLOWED AND MASSIVE BASALT
8. THOLEIITIC PILLOWED AND MASSIVE BASALT WITH SUBORDINATE PILLOWED AND GLOBULAR (IN PECHENGA) FERROPICRITE
9. FERROPICRITIC TUFF
10. FINELY LAMINATED, PARTLY SYNSEDIMENTARY-FOLDED ORGANIC CARBON- AND SULPHIDE ENRICHED ARKOSIC TO GRAYWACKE SANDSTONE, SILTSTONE, MUDSTONE, IN PLACES (PECHENGA) WITH SULPHIDE AND CARBONATE CONCRETIONS; FERROPICRITE FLOW AND TUFF, IN PLACES (PECHENGA) WITH CALCAREOUS CONCRETIONS; IN PECHENGA - SEVERAL BODIES OF CURRENT-BEDDED AND CURRENT-RIPPLED ARKOSIC GRITSTONE, SANDSTONE AND CONGLOMERATE (ALLUVIAL FANS); BASALTIC LAVA AND TUFF
11. LIMESTONE
12. DOLOMITE, DOLOLITHITE WITH SUBORDINATE LIMESTONE
13. RED COLOURED HEMATITE-ENRICHED SANDSTONE
14. MAGNETITE-ENRICHED ACIDIC ROCK, QUARTZ-KERATOPHYRE AND AMPHIBOLITE
15. ALKALINE BASALT WITH SUBORDINATE ANDESITIC DACITE, MUGEARITE AND ALKALINE PICRITE
16. MUGEARITE AND ALBITOPHYRE
17. QUARTZITE
18. BASALT
19. KOMATIITIC BASALT, BASALTIC ANDESITE
20. POLYMICT CONGLOMERATE
21. OROGENIC SUBVOLCANIC ANDESITE
22. Ni-Cu-BEARING DIFFERENTIATED GABBRO-WEHRLITE INTRUSION

- FORMATION (a) AND MEMBER (b) BOUNDARIES
- NONDEPOSITIONAL BREAK
- INFERRED OROGENIC DISCONFORMITY
- REGOLITH (a) AND PALEOSOL (b) LEVELS
- INFERRED THRUST BOUNDARY

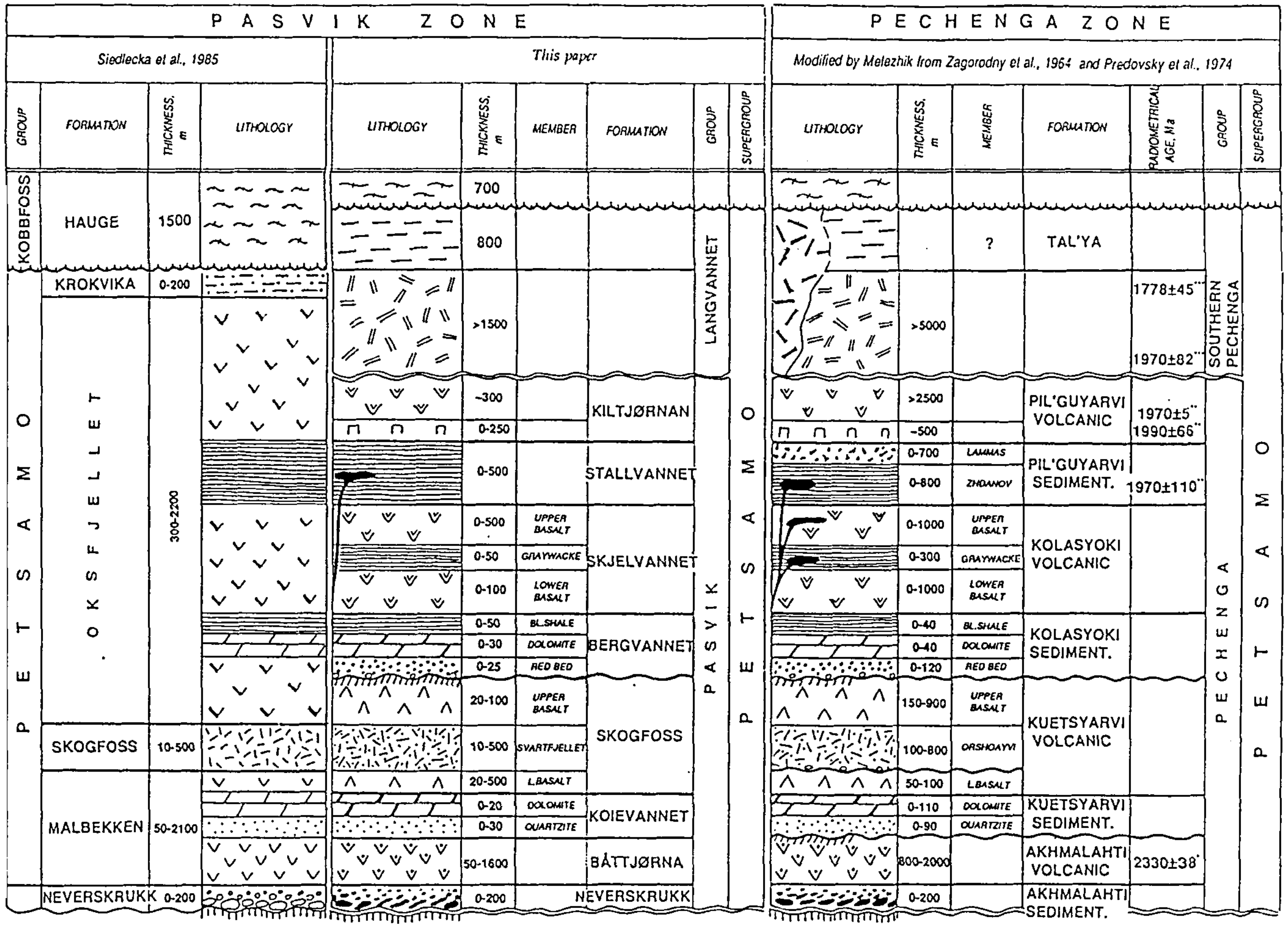


TABLE 3

CHEMICAL COMPOSITION OF THE CARBONATE ROCKS OF THE KOIEVANNET FORMATION

No	SiO2	Al2O3	Fe2O3	TiO2	MgO	CaO	Na2O	K2O	MnO	P2O5
PS-105	1.64	0.22	0.03	<0.01	21.08	31.64	<0.10	0.09	0.03	0.11
PS-106	37.11	1.5	0.17	0.02	12.81	26.22	0.13	0.05	0.03	0.07
PS-107	12.92	1.08	0.15	0.04	5.37	45.31	0.12	0.18	0.07	0.1
PS-108	16.06	0.96	0.14	0.02	21.28	26.95	0.1	0.04	0.04	0.13
PS-109	29.04	0.87	0.09	0.02	8.28	35.65	0.15	0.09	0.05	0.09
PS-110	21.83	0.77	0.04	0.02	17.24	28.32	<0.10	0.11	0.03	0.11
PS-111	1.61	0.09	<0.01	<0.01	17.46	34.94	<0.10	<0.01	0.03	0.19

TABLE 4

CHEMICAL COMPOSITION OF THE PICRITIC VOLCANICS AND VOLCANOCLASTIC SEDIMENTS OF THE LONGVANNET GROU

No	SiO2	Al2O3	Fe2O3	TiO2	MgO	CaO	Na2O	K2O	MnO	P2O5	Gl.tap	Tot.
PS-130	42.31	8.51	14.54	1.43	17.49	9	0.24	0.07	0.2	0.12	5.22	99.14
PS-131	42.84	7.9	13.61	1.58	18.14	9.13	<0.10	0.05	0.19	0.15	4.88	98.53
PS-132	42.33	8.94	14.1	1.08	19.34	7.6	<0.10	0.06	0.18	0.13	5.23	99.07
PS-133	46.96	5.25	11.44	0.99	19.12	9.51	<0.10	0.07	0.17	0.08	5	98.63
PS-134	35.54	7.64	12.07	2.16	15.18	14.5	0.17	0.04	0.21	0.26	10.14	97.92
PS-135	48.3	4.95	11.37	1.1	19.3	10.1	<0.10	0.05	0.17	0.09	3.46	98.9
PS-136	44	7.71	12.58	1.46	19.53	8.34	<0.10	0.05	0.17	0.13	5.19	99.22
PS-137	22.76	13.98	15.11	2.11	14.22	13.45	<0.10	0.03	0.22	0.23	16	98.18
PS-138	42.89	9.79	15.22	1.76	16.38	7.76	0.62	0.08	0.18	0.16	4.62	99.47
PS-139	44.05	9.73	14.34	1.78	15.82	7.87	0.94	0.08	0.17	0.17	4.4	99.36
PS-140	42.98	9.58	14.76	1.71	15.99	8.44	0.69	0.08	0.18	0.19	4.79	99.38
PS-141	45.22	9	14.26	1.6	15.77	8.23	0.93	0.1	0.17	0.16	4.14	99.59
PS-142	46.63	8.02	13.46	1.51	15.4	8.65	1.05	0.1	0.17	0.15	4.07	99.21
PS-143	45.67	8.5	13.89	1.58	15.44	8.4	0.98	0.09	0.17	0.15	4.45	99.34

LEGEND

PETSAMO SUPERGROUP (ca.2.4-1.8 Ga)
Metamorphosed supracrustal and plutonic rocks

LANGVANNET/SOUTHERN PECHENGA GROUPS (1.99-1.8 Ga)

SUPRACRUSTAL COMPLEX

1	Sandstone with thin bands of siltstone
2	Amygdaloidal and banded amphibolite, in places, massive and pillowed basalt
3	Postorogenic andesitic volcanoclastic sandstone to siltstone; subordinate andesitic tuff, basalt
4	Postorogenic andesitic volcanoclastic conglomerate
5	Andesitic volcanic and volcanoclastic sediment with subordinate picrite and basalt
6	Andesitic volcanoclastic carbon-sulphide-enriched sandstone, siltstone
7	Quartzite (mainly metamorphosed chert)
8	Carbonate rock
9	Picritic basalt
10	Synorogenic extrusive (70%) and effusive (30%) andesite (bimodal picrite-andesite volcanic association) (1970±82 Ma)
11	Synorogenic andesitic lava-breccia (10%), volcanic agglomerate (75%), tuff (15%) (bimodal picrite-andesite volcanic association)
12	Synorogenic picritic pillowed lava (20%), lava-breccia (70%), tuff (10%) (bimodal picrite-andesite volcanic association); picritic volcanoclastic conglomerate, sandstone, siltstone, mudstone (submarine seismic slope-slide); subordinate basalt
13	Andesitic volcanoclatic sandstone to siltstone with andesitic tuff, chert and carbonate rock
14	Carbon-sulphide-bearing sandstone, siltstone, mudstone with chert

INTRUSIVE COMPLEX

15	Pyroxenite, gabbro

PORITASH FORMATION

16	Synorogenic andesitic subvolcanic body and dike (1778±45)

PASVIK/PECHENGA GROUPS (2.4-1.99 Ga)

SUPRACRUSTAL COMPLEX

KILTJØRNAN/PIL'GUYARVI VOLCANIC FORMATIONS

17	Pillowed tholeiitic basalt, lava-breccia, massive basalt (1980±44 Ma)
18	Acidic tuff (1970±82 Ma)
19	Pillowed to massive and globular (in Pechenga) ferropicrite (1990±66 Ma)

STALLVANNET/PIL'GUYARVI SEDIMENTARY (PRODUCTIVE) FORMATIONS

20	Finely laminated, partly synsedimentary-folded organic carbon- and sulphide-enriched arkosic to graywacke sandstone, siltstone, mudstone, in places (Pechenga) with sulphide and carbonate concretions; ferropicrite flow and tuff, in places (Pechenga) with calcareous concretions; in Pechenga - several bodies of current-bedded and current-rippled arcosic gritstone, sandstone and conglomerate (alluvial fan); basaltic lava and tuff

SKJELVANNET/KOLASYOKI VOLCANIC FORMATIONS

21 Tholeiitic basalt with pillow and beccia structure horizon of carbonaceous sulphide-bearing graywacke sandstone, siltstone; basaltic tuff and tuffitic with subordinate limestone

22 Carbonaceous sulphide-bearing graywacke sandstone, siltstone; basaltic tuff and tuffitic with subordinate limestone

BERGVANNET/KOLASYOKI SEDIMENTARY FORMATIONS

23 Current-bedded red-coloured volcanoclastic polymict conglomerate, hematite-magnetite-enriched gritstone, sandstone, siltstone and mudstone (in Pechenga with mud-cracks); dolomite, stromatolitic dolomite (in Pechenga), dololithit, limestone, jasper (in Pechenga); tuffitic carbonaceous sulphide-bearing siltstone

SKOGFOSS/KUETSYARVI VOLCANIC FORMATIONS

24 Amygdaloidal alkaline basalt, andesitic dacite, mugearite with breccia structure

25 Amygdaloidal alkaline basalt (partly both pillow and columnar, in Pechenga) with subordinate mugearite

26 Volcanoclastic conglomerate with volcanic bombs

27 Mugearite and albitophyre with breccia structure

28 Amygdaloidal alkaline basalt, alkaline picrite

KOIEVANNET/KUETSYARVI SEDIMENTARY FORMATIONS

29 Red-coloured current-bedded (synsedimentary-folded in Pechenga) sandstone; red-coloured dolomite, onkolitic dolomite, dololithite

BÅTTJØRNA/AKHMALAHTI VOLCANIC FORMATIONS

30 Porphyritic and amygdaloidal basalt, subordinate basaltic andesite (2330±38 Ma)

31 Volcanoclastic graywacke sandstone

NEVERSKRUKK/AKHMALAXTI SEDIMENTARY FORMATIONS

32 Basal polymict conglomerate, gritstone, sandstone

INTRUSIVE COMPLEX

33 Gabbro-wehrlite (Ni-Cu-bearing formation) (ca.1,99 Ga)

34 Gabbro

GEOLOGICAL SYMBOLS

Lithological boundary

Inferred lithological boundary

Electromagnetic conducter

Volcanic centre (andesitic volcanism)

Volcanic centre (ferropicritic volcanism)

Inferred thrust boundary

Fault

Inferred fault

Strike and dip of bedding

Drill hole

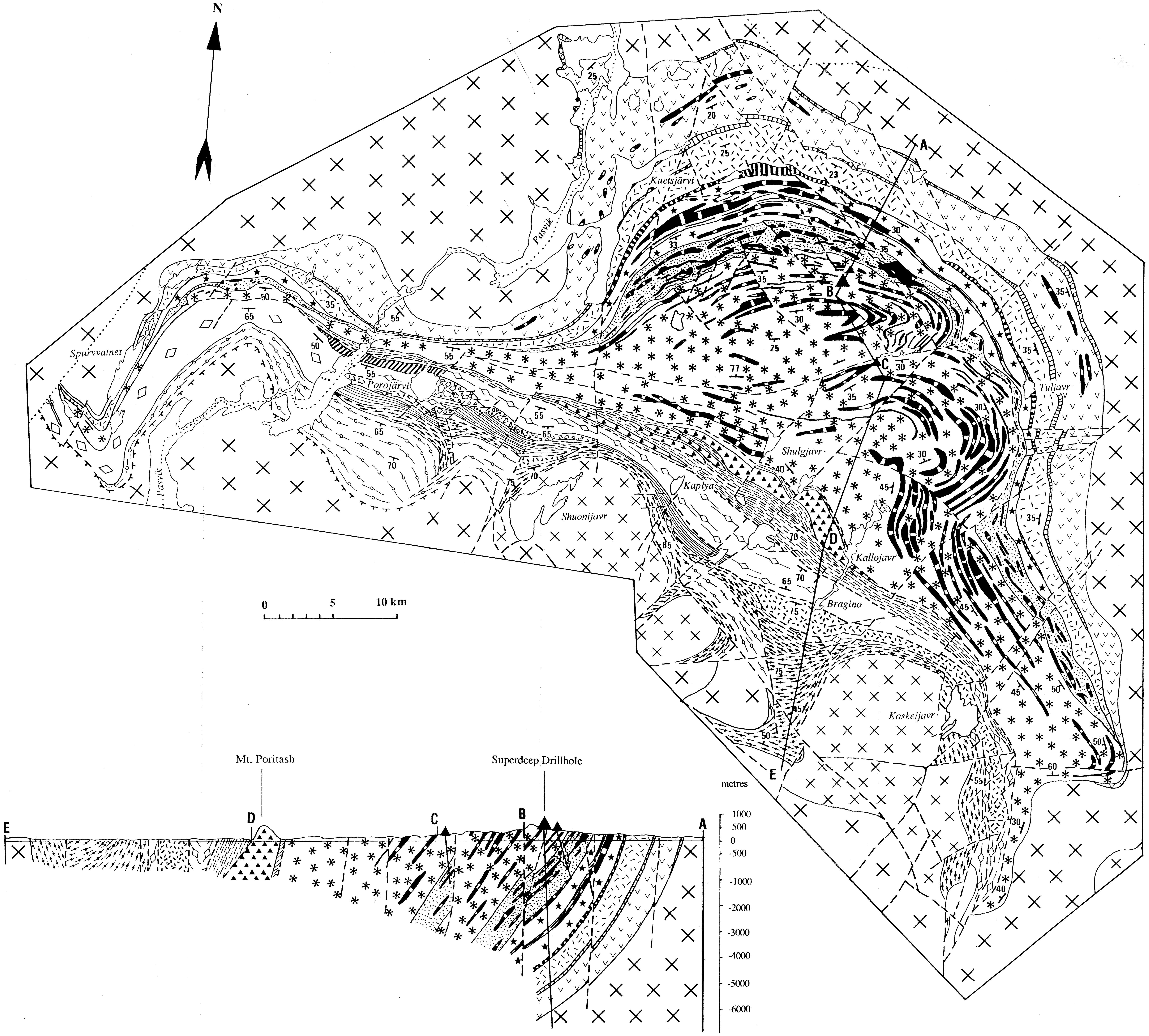
GEOLOGICAL MAP

OF THE PASVIK-PECHENGA BELT

by

V. A. MOKROUSOV, L. S. MOLOTKOV (Central Kola Geological Expedition, Monchegorsk), G. JUVE, V. A. MELEZHIK, L. P. NILSSON, B. A. STURT, (Geological Survey of Norway, Trondheim), D. M. RAMSAY (University of Glasgow, Glasgow), P. K. SKUF'IN (Geological Institute Russian Academy of Sciences, Apatity).

Compiled in 1994/95 by V. A. MELEZHIK (Geological Survey of Norway, Trondheim)



LEGEND

PETSAMO SUPERGROUP (2.45-1.85 Ga)

SOUTH PECHENGA/LANGVANNET GROUPS (1.95-1.85 Ga)

METASUPRACRUSTAL ROCKS

LAKE PESTCHANOE FORMATION

THOLEIITIC PILLOWED AND AMYGDALOIDAL BASALT

TAL'YA FORMATION

SANDSTONE WITH THIN BANDS OF SILTSTONE

KASESJOKI FORMATION

ANDESITIC VOLCANOCLASTIC SANDSTONE

ANDESITIC VOLCANOCLASTIC POLYMICT CONGLOMERATE

KAPLYA FORMATION

SYNOROGENIC ANDESITIC AND DACITIC LAVA AND TUFF, EXPLOSION BRECCIA (COLD AND HOT LAHAR),

MENNEL' FORMATION

SYNOROGENIC PICRITIC BASALT, PICRITIC LAVA, LAVA-BRECCIA, TUFF, PICRITIC SEDIMENT

FAGERMO FORMATION

SYNOROGENIC ULTRAMAFIC PILLOWED AND MASSIVE LAVA, LAVA-BRECCIA, TUFF, ULTRAMAFIC SEDIMENT

BRAGINO FORMATION

SYNOROGENIC ANDESITIC AND DACITIC LAVA, TUFF, TUFFITE, ANDESITIC VOLCANOCLASTIC SEDIMENT, SUBORDINATE BASALT AND PICRITE, BONINITIC ANDESITE

KALLOJAVR FORMATION

C_{ORG} AND SULPHUR-RICH SANDSTONE, SILTSTONE, MUDSTONE WITH CHERTY QUARTZITE AND SUBORDINATE BASALT AND ANDESITE

LANGVANNET GROUP (undivided)

BASALT, ANDESITE, ANDESITIC VOLCANOCLASTIC SEDIMENT, C_{ORG} AND SULPHUR-RICH SANDSTONE, CHERTY QUARTZITE, AMPHIBOLE SCHIST

METAINTRUSIVE ROCKS

PORITASH SUBVOLCANIC OROGENIC ANDESITE, DACITE, RHYOLITE

NORTH PECHENGA GROUP (2.45-1.95 Ga)

METASUPRACRUSTAL ROCKS

PILGUJÄRVI VOLCANIC FORMATION

THOLEIITIC PILLOWED AND MASSIVE BASALT, BASALTIC LAVA-BRECCIA, RHYOLITIC AND DACITIC EXPLOSION BRECCIA (COLD AND HOT LAHAR)

ULTRAMAFIC (FERROPICRITIC) FLOW, SILL AND INTRUSION (undivided)

PILGUJÄRVI SEDIMENTARY FORMATION

ULTRAMAFIC (FERROPICRITIC) LAVA, TUFF AND TUFFITE; C_{ORG} AND SULPHUR-RICH GREYWACKE AND ARKOSIC SANDSTONE, SILTSTONE, MUDSTONE

ULTRAMAFIC (FERROPICRITIC) EXPLOSION BRECCIA (only in the cross-section)

KOLASJOKI VOLCANIC FORMATION

THOLEIITIC BASALT WITH PILLOW AND STRUCTURE, BASALTIC TUFF AND TUFFITE

C_{ORG} AND SULPHUR-RICH SANDSTONE AND SILTSTONE

KOLASJOKI SEDIMENTARY FORMATION

TUFFITIC CARBONACEOUS SILTSTONE, Mn-RICH DOLOSTONE, STROMATOLITIC DOLOSTONE, DOLOLITHITE, JASPER, RED-COLOURED CURRENT-BEDDED HAEMATITE-RICH SANDSTONE, POLYMICT CONGLOMERATE

KUETSJÄRVI VOLCANIC FORMATION

AMYGDALOIDAL AND COLUMNAR-JOINTED SUB-ALKALINE BASALT, AMYGDALOIDAL ALKALINE BASALT, ANDESITE, DACITE, RHYOLITE AND MUGEARITE

BROWNISH RED VOLCANOCLASTIC CONGLOMERATE, VOLCANOCLASTIC MUDSTONE WITH VOLCANIC BOMBS, SILTSTONE

KUETSJÄRVI SEDIMENTARY FORMATION

RED AND MULTICOLOURED DOLOSTONE, ONCOLITHIC DOLOLITE, RIPPLE-MARKED DOLOLITHITE, DOLOMITIC BRECCIA AND CONGLOMERATE, RED COLOURED ARKOSIC AND QUARTZITIC SANDSTONE

AHMALAHTI VOLCANIC FORMATION

PORPHYRITIC AND AMYGDALOIDAL SUB-ALKALINE BASALT, BASALTIC ANDESITE, DACITE, KOMATIITIC ANDESITE, MAFIC AND ULTRAMAFIC TUFF, GREYWACKE SANDSTONE

NEVERSKRUKK FORMATION

BASALTIC TUFF, ARKOSIC SANDSTONE, GRITSTONE, BASAL POLYMICT CONGLOMERATE AND BRECCIA

METAINTRUSIVE ROCKS

GABBRO AND GABBRO-DOLERITE SILL (undivided)

SYNOROGENIC GRANITE, GRANODIORITE, DIORITE

ARCHAEAN ROCKS (2.9-2.5 Ga)

TONALITE, GRANITE, GNEISS, AMPHIBOLITE, MAFIC AND ULTRAMAFIC INTRUSIONS

GEOLOGICAL SYMBOLS

LITHOLOGICAL BOUNDARY (unspecified)

FAULT (unspecified)

INFERRED THRUST BOUNDARY

25 STRIKE AND DIP OF BEDDING

DRILLHOLE