melt generated by crustal contamination, which decreases the solubility of sulfur in the silicate magma. Meanwhile, these elements are depleted in the silicate magma in which sulfide segregation occurs. Therefore sulfide melts segregated from silicate magma probably related to the genesis of the Noril'sk deposits.

The existence of the lavas which are depleted in chalcophile elements may be one of the indicators which suggest the existence of orthomagmatic sulfide deposit in the depth.

1-3-4 Intrusions

(1) Intrusions

There are fifteen types of intrusive rocks in the Noril'sk region (Fig. II-1-3-5). Each type has its own geochemical and isotopic characteristics and some are considered to be comagmatic with lavas. Most of the intrusions intrude into the Tungusskaya series of Paleozoic, and exist within 2 km from the bottom of basaltic rocks (Fig. II-1-3-8). Although many drillings for petroleum prospecting were carried out in the Noril'sk region, the intrusions have not been discovered in the lower part of the Paleozoic formations. Almost all of the intrusions are sills that conformably intruded along the bedding of Paleozoic formations. However, some sills intruded along the tectonic structural lines. The thickness of many sills ranges between several meters to a hundred meters, but some sills reaches 150 to 200 meters in thickness.

Mineralization of sulfides is not observed in all sills. It is observed only in the "fully differentiated" sills which include picritic part. The amount of these mineralized sills occupy only 0.01 volume percent within the entire magmas of the Noril'sk region (Table II-1-3-3).

(2) Noril'sk Type Ore-Bearing Intrusion and Lower Talnakh Type Intrusion

The intrusions accompanied with economical mineralization are known as the Noril'sk type ore-bearing intrusion. This type is fully differentiated from picritic gabbrodolerite to leucogabbro (Fig. II-1-3-9). MgO varies from 29 to 4 wt%, from the lower to the upper in a intrusion, and economical disseminated ore and massive ore are included in the picritic unit of the lower part. There are only three Noril'sk type ore-bearing intrusions in the Noril'sk region. These are the Talnakh intrusion and the Kharaelakh intrusion in the Talnakh Ore Junction, and the Noril'sk-I intrusion in the Noril'sk Ore Junction. These intrusions are distributed closely relating to the Noril'sk-Kharaelakh fault.

The geologic section of the Talnakh intrusion is shown in Fig. II-1-3-10. As shown in the figure, the Lower Talnakh type intrusion is located with close relationship to the Noril'sk type ore-bearing intrusion (Talnakh intrusion). This intrusion is generally found a few tens to hundreds meters beneath the Noril'sk type ore-bearing intrusion. The Noril'sk type ore-bearing intrusion involves economical mineralization. The Lower Talnakh type intrusion also

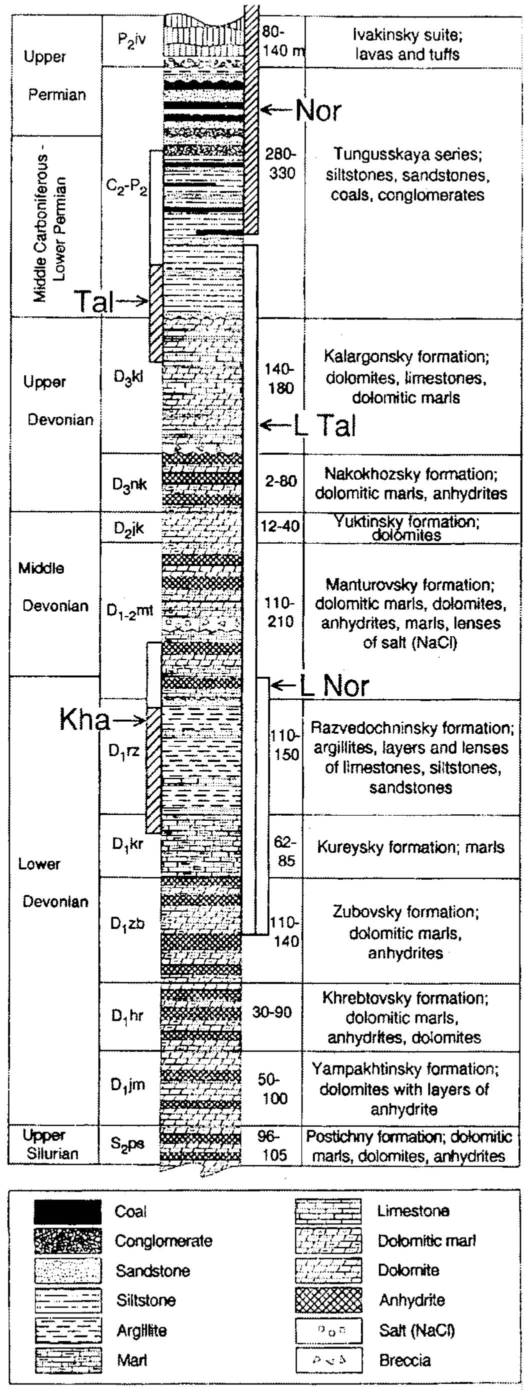

Fig. II-1-3-8 Generalized stratigraphic column for Silurian to Permian formations based on typical stratigraphic thickness for the Tanlakh ore junction (Czamanske et al., 1995)

Vertical bars show the approximate ranges in stratigraphic position of the base of each intrusion : Nor=Noril'sk; L Nor=Lower Noril'sk; Tal=Talnakh; L Tal=Lower Talnakh; Kha=Kharaelakh

Rock unit		Modal % olivine	MgO wt %	Notable phases
Leucocratic gabbro		0-3	4-8	Pl_1
Quartz diorite (Russian: quartz gabbrodiorite)		0	1.2-1.7	Pl_2 + Aug + Qtz
Magnetite gabbro		0-4	4.4-7	Pl_2 + Aug + Mt
Prismatic gabbro (Russian: gabbro-diorite)		0-5	6-7	Pl_2 + Aug
GABBRODOLERITE	Olivine-bearing	3-7	6-8	Pl_2 + Aug + Ol_2
	Olivine	10-27	9-12	Pl_2 + Aug + Ol_2 + sparse Pl_1
	Picritic	40-80	18-29	Ol_1 + Pl_2 + Aug + Sulfide + Pl_1 glom + sparse Pl_1
	Taxitic	7-18	9-16	Pl_2 + $Ol_{1,2}$ + Aug + Sulfide + Pl_1 glom
	Contact	10-15	7-8	Pl_2 + Aug + Ol_2

Fig. II-1-3-9 Generalized lithologic section for the "fully differentiated" main body of the ore-forming intrusions (Czamanske et al., 1995)

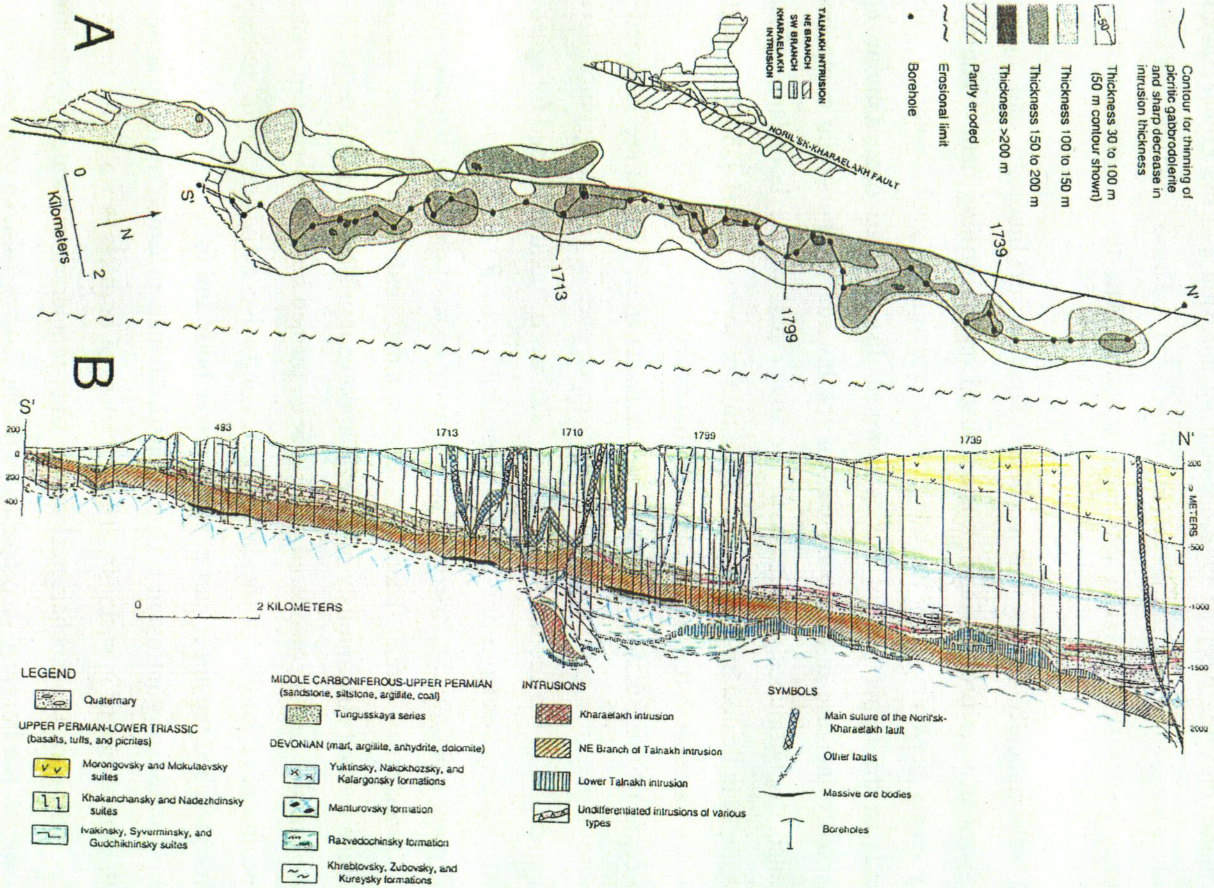

Fig. II-1-3-10 **A) Projection to the surface of the main body of the NE and SW branch of the Talnakh intrusion (Czamanske et al., 1995); B) Cross section of the thickest part of the NE branch of the intrusion (Czamanske et al., 1995)**

involves copper-nickel-PGE mineralization, which is not economical.

The Noril'sk type ore-bearing intrusion and the Lower Talnakh type intrusion have different intrusive feature compared to other intrusions. Though most of intrusions intrude along the bedding plane, only the Noril'sk type ore-bearing intrusion and the Lower Talnakh type intrusion intrude with cutting bedding plane (Fig. II-1-3-11). These structures are called "insertion" by Russian geologists, and are considered to contaminate the country rocks on a large scale.

Fig. II-1-3-12 schematically shows the vertical variations of lithology and mineral assemblage of the Noril'sk type ore-bearing intrusion based on the drilling data. The most important boundary exists between picritic gabbrodolerite and olivine gabbrodolerite. This boundary corresponds to the upper part of the economical disseminated ore. Olivine and sulfide contents markedly increase in the lower part of the boundary. Forsterite component and Ni in olivine also discontinuously increase in the lower part of the boundary. These discontinuous changing is indicated by chemical composition of rocks (Fig. II-1-3-13). MgO, Cu, Ni and Pd markedly increase in the lower part of the boundary.

There are two types of ores, disseminated ore and massive ores. These are included in picritic gabbrodolerite and taxitic gabbrodolerite. The upper part of picritic gabbrodolerite corresponds to the upper part of the economic ore body. The word "taxitic" is used for igneous rocks which show various textures from fine-grained to pegmatitic by Russian geologists. The massive ore generally intrudes into the Paleozoic sedimentary rocks underlying intrusions and discontinuous with disseminated ore. Therefore, disseminated and massive ores are not considered to have been formed continuously by precipitation of immiscible sulfide melts. As mentioned below, the massive ore is considered to have been formed by the intrusion of mobile sulfide melt into the intrusive bodies in the last stage of intrusive activities. The intruded sulfide melt sometimes reached the upper part of the intrusive body and formed veins.

The Noril'sk type ore-bearing intrusion is characteristically accompanied by thick hornfels halos compared with other types of intrusions. The thickness of hornfels is 1.5 to 2.5 times of the intrusion itself. The hornfels is characterized by high-temperature hornfels containing clinopyroxene. However, the hornfels accompanied with the Lower Talnakh type intrusion is lower temperature hornfels containing hornblende and biotite, and its thickness is only 0.5 to 1.5 times of the intrusion itself. The thickness of hornfels of other types of intrusions becomes thinner and the thickness is thinner than that of intrusion itself. Therefore, the Noril'sk type ore-bearing intrusion might have been the highest temperature intrusion in all types of intrusions and have given thermal effect to its host rocks.