before, during, and after the emplacement of the intrusions and their mineralization, controlled their level of intrusion and any eventual disruption within them. Likewise, tensional or compressional forces along the fault before, during, or after the intrusion and its mineralization, controlled the distribution and morphology of the thick parts of the intrusion; these consist of thick massive sulphides within negative folds in the floor, while their lateral extensions are terminated by positive folds in the floor.

The deposits

The mineralized intrusions are up to 12 km long and up to 2 km wide, and resemble differentiated sills (Figures 2.11, 2.12). Using data of Duzhikov *et al. (op. cit.)*, I have found the sills to average 180 m in thickness for seven ore junctions, but they may attain thicknesses of 350 m. The upper zone, with an average thickness of 30 m, consists of hybrid rocks (leucogabbros to diorites) and an important inhomogeneous, mineralized, chromite-bearing gabbro-dolerite. The 100 m-thick middle or major layered zone contains (from the top) quartz- or olivine-bearing gabbro-dolerites and biotite–olivine gabbros; and a basal picritic gabbro-dolerite with disseminated mineralization.

The 25 m-thick basal zone is made up of dunite to taxitic (compositionally and texturally inhomogeneous) gabbro-dolerite containing heavy disseminations of sulphides, with massive sulphides at the base (0 to 40 m thick). A 2 m contact selvage comprises the basal contact with the country rock. If the latter is calcareous, skarns are developed.

The massive mineralization occurs as sheets or pods, depending on its position in the sill and in the footwall troughs where, as indicated above, the thickness of the sill and the massive and disseminated mineralization increases in sympathy. The orebodies have a complex zoning, which need not concern us here. The existence of copper-rich veins and brecciated ores either indicates a separate ore intrusion (as some Russian geologists believe) or a late-stage mobilization of the ore. Such veins transgress the sill rocks and those of the contact-metamorphic aureole. Duzhikov *et al. (op. cit.)* recognize that the ore junctions are not equally mineralized. The Talnakh junction shows the best mineralization (veinlike and massive breccia types at the top contact, disseminations throughout all the zones, and veinlet to massive ores at the base). The Noril'sk junction has no sulphides at the top of the contact, but veinlet to massive ore occurs in the footwall of the sills. The Imangdinski junction contains disseminated sulphides only in the upper and the middle zones.

Some geologists in Russia regard the chromite-bearing, petrographically and texturally heterogeneous (taxitic) gabbro-dolerite layer of the upper zone, which is sandwiched between two homogeneous leucocratic to anorthositic envelopes, as a separate intrusion — others regard it as a conventional product of a single convecting magma. The taxitic gabbro is often pegmatoidal, with rounded, dark olivine-rich and iron-rich chromite segregations surrounded by 5–10 mm anorthosite rims called 'spots' (or 'boulders'), which contain very high values and anomalous amounts of secondary minerals. This is regarded as a new ore discovery, and what makes the layer of considerable interest is its high grade, with PGE values up to 40 g/t and Pt:Pd ratios as high as 1:0,7.

2.2.2. *The Deposits of the Kola Peninsula*

Very few details of the PGE content of the Russian nickel–copper ore deposits of the Kola Peninsula are known, except that they have a similar morphology, stratigraphy, and age as the Finnish deposits (Section 2.3), and that their PGE content is low, with Pt:Pd ratios of between 1:2 and 1:4 (Razin, 1977). There are five ore districts (Pechenga, Allarechensk, Monchegorsk, Imandra-Varzuga, and Lovozero), in which the Karelide rocks occur in a northwest-trending early Proterozoic graben along the axis of the Kola peninsula, at the junction of two Archaean blocks (Smirnov, 1966). Two major intrusions, the Oulanka layered complex (southwest of the White Sea) and the Burakovsky intrusion (just east of lake Onega), occur outside the Kola peninsula. Their lithologies have been described (Vermaak, 1989), but little is known of their mineralization.

Of the Kola deposits, only the nickel-rich Monchegorsk (also Monchetundra) deposit was mined extensively from 1937 to 1968, when its ore was apparently exhausted. The PGE content was low, between 0,04 and 0,4 g/t, distributed as follows

Pt 23,2%
Pd 76,0%
Ru 0,1%
Rh 0,5
Ir 0,2% (no Os).

Vermaak (1989) provided details of the geology of the Monchegorsk and easterly Federovatundra and Panskitundra deposits. The most easterly Pechenga ore field contains more than 20 nickel–copper deposits and showings, occurring in a 60 km south-bending arc up to 35 km wide (dips 35 to 80 °SW). Some 80 per cent of the Proterozoic rocks consist of 10 to 12 km thickness of lavas and basic igneous rocks with minor interlayered sediments. More than 110 nickel-bearing basic and ultrabasic intrusions and 60 gabbro-dolerite intrusions occur over the 60 km of the Pechenga arc, with a thickness and length of from 200 to 700 m.

All the deposits occur in the folded centre of the arc. The primary ore deposits are found in the lower ultrabasic to basic layers of the intrusives, particularly in the basal serpentinites. The sulphides are either massive, or occur as brecciated ores or offset veins intruding in the footwall rocks. The Kaula and Zhdanovskaya deposits, and the structural aspects of the ores of the Pechenga group, have been discussed by Smirnov (1989).

2.2.3. *Economics*

Talnakh is the most important ore junction of the Noril'sk-Talnakh area, containing the huge Talnakh

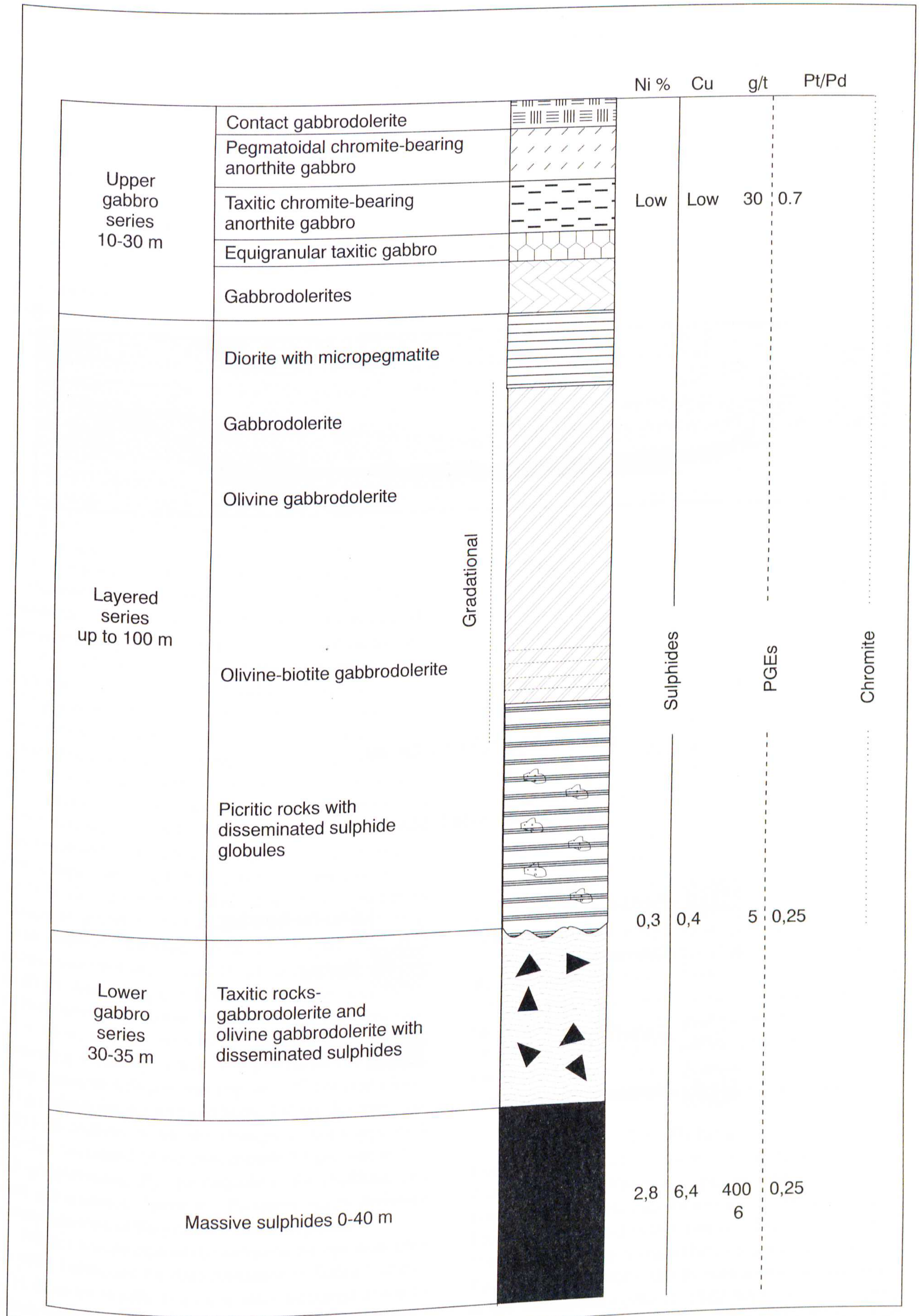

FIGURE 2.11. Typical section through the mineralized intrusion at Talnakh (courtesy Professor M.J. Viljoen)