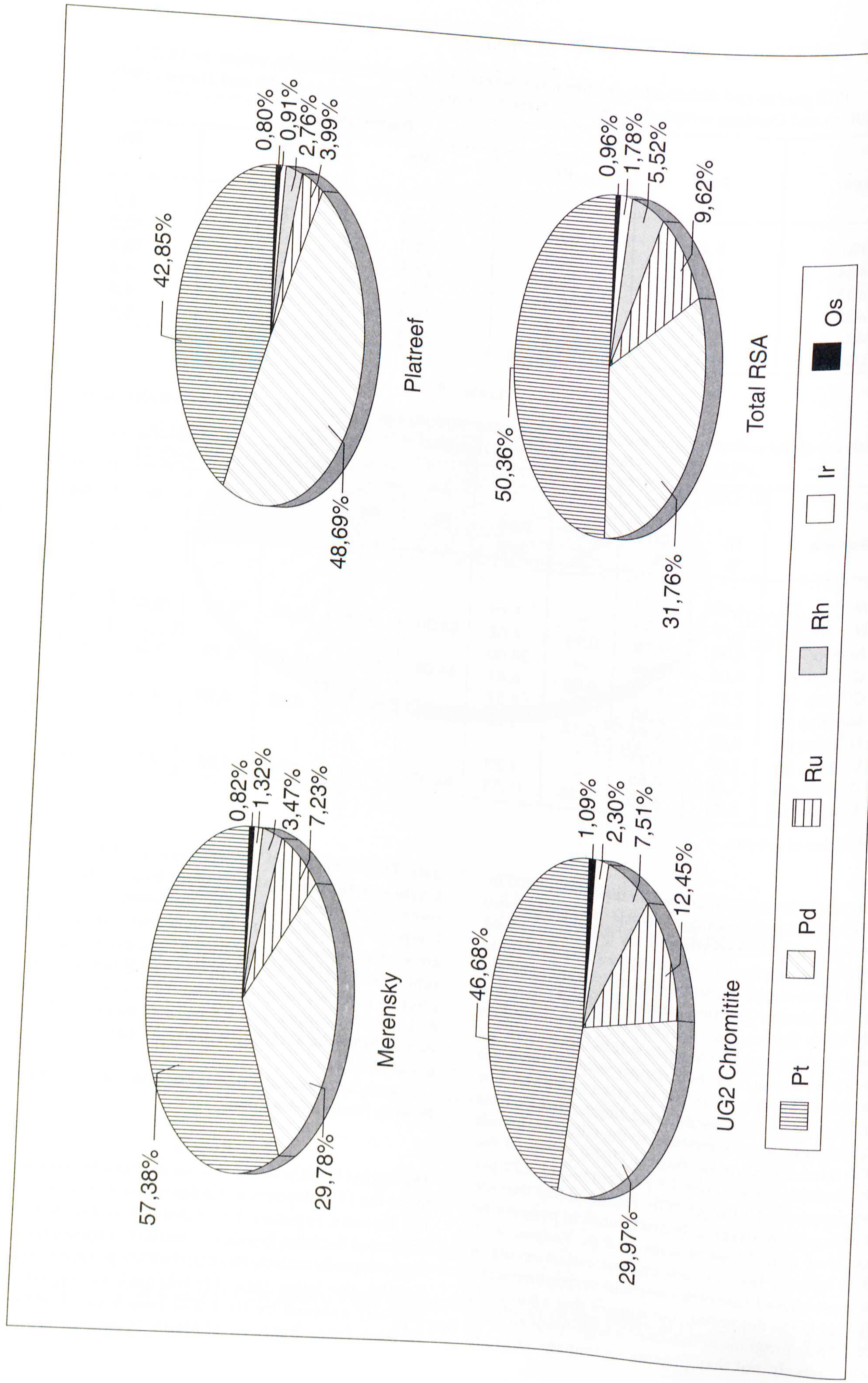

FIGURE 2.8. Percentage distribution of the individual PGM in South African ores (based on in-situ tonnages)

extension of the Finnish deposits (Section 2.3), with which they have a close geological affinity and dating.

Historical production of the PGE in Russia was from placer deposits in the Ural mountains, which are now largely depleted (see below). The second-oldest PGE deposits in Russia occur at Pechenga and Monchegorsk in the Kola Peninsula. The newest and largest rift-related copper–nickel deposits occur in the Noril'sk-Talnakh area of Siberia; these are currently the most important by-product PGE producers in Russia. Due to the severe restrictions on Western scientific visitors to most ore deposits in Russia in the past, details remain obscure. However, since the advent of 'glasnost' and 'perestroika', many Western geologists have had a cursory look at the deposits, and many geological gaps are currently being filled by the Russian geologists enjoying a new scientific freedom. Nevertheless, vital data on tonnage and grade remain pretty much guesswork, clothed as they are in the usual secrecy. Some insight into the mysteries of these Russian deposits is provided below.

2.2.1. *The Noril'sk-Talnakh Deposits*

The geology of the Noril'sk-Talnakh deposits has recently been described in considerable detail by Duzhikov and Duzhikov *et al.* (1992), and also by Naldrett (1990, 1991, 1992) and Von Gruenewaldt (1989, 1990) following their visits to the area. The deposits are being exploited by a large number of mines near the town of Noril'sk in the province of Krasnojark, north of the Arctic Circle. In this area, the Siberian platform is bordered by the northeast-trending Yenesi trough in the east and by the roughly east-west-trending Khatanga trough in the north. Deposition in these troughs caused tensional conditions in the adjoining platform. The differentiated intrusions that host the ore deposits of the region were preceded by three fundamental geological events (Figures 2.9, 2.10) that controlled their morphological and structural setting:

- the deposition of thick sedimentary successions
- a long period of intermittent tectonic reactivation of a multi-branched, north-trending rift system on the platform, resulting from that sedimentation
- eruption of the thick sequence of the Siberian (lava) traps, and the emplacement of their intrusive counterparts.

The major sedimentary deposition commenced in the late Proterozoic and continued into the late Mesozoic-Cenozoic, giving rise to some 8000 to 9000 m of sediments. The 4000 m of Proterozoic to Devonian marine, lagoonal to lacustrine sediments (dolomites, limestones, sandstones, marls, siltstones, argillites, gypsum anhydrite, and sulphate-rich evaporates) were followed by continental conglomerates, sandstones, siltstones, and coal measures from the middle Carboniferous to the Upper Permian. The superpositioning of these thick sedimentary groups on the mature cratonic crust repeatedly activated tectonic movements along the pre-existing NNE- to NE-trending, multi-branched, deep rift faults and their lateral counterparts, causing the outpourings of huge volumes of about 4000 m of effusive sub-alkaline, ultrabasic, or tholeiitic lavas from the late Permian to the mid Triassic. This type of volcanism was experienced globally — South Africa's Drakensberg lavas being a counterpart of these rocks. Naldrett *et al.* (1992) recognized five principal magma types that gave rise to these flood basalts on the Siberian craton (base to top): a fractionated type with alkaline affinities; a nickel-rich suite including picrite basalts; a primitive nickel-depleted suite also including picrite basalts; a crustally contaminated suite; and a transition to a second primitive suite, again including picrite basalts. Three upper suites consist of uncontaminated tholeiites and tuffs, which those authors did not study.

There are various unmineralized and undifferentiated, to sulphide-bearing and differentiated, intrusive equivalents of these flood-basalt suites. Naldrett *et al.* (*op. cit.*) again recognize five types: alkaline intrusions, titanium-rich dolerite dykes, dolerite dykes and sills, barren differentiated bodies, and differentiated bodies related to the so-called ore junctions, that is, exploitable mineralized centres in which a number of ore deposits may occur in layered complexes at different levels. Duzhikov *et al.* (1992) envisage a complex system of magma chambers at different levels in the crust, caused by the periodic reactivation of one or more deep rift faults, in order to account for the diversity of magma types. They also postulate a set of shallow magma chambers in which the comagmatic base-metal sulphides were continually being fractionated and concentrated, until the immiscible sulphides were eventually intruded at a late stage as an ore magma in their own right. According to Duzhikov *et al.* (1992), other diverse types of intrusives such as carbonatites and kimberlites, as well as mineralization in the form of porphyry copper, polymetallic, copper–zeolite, and mercury–antimony–arsenic deposits, also used the intensive rifting and related faulting of the area for their emplacement.

The layered complexes

Duzhikov *et al.* (*op. cit.*) consider that a comagmatic relationship exists between the picritic basalts and the ultramafic (picritic) intrusives. There is an obvious relationship between the latter mineralized bodies and two major, NNE-trending deep-seated rifts. The South Noril'sk, Noril'sk, Talnakh, and Talminsky ore junctions occur over a distance of 250 km (from south to north) along the Noril'sk-Kharayelakh fault. To the east, the parallel Imangdinsky-Lefninsky fault contains the Imangdinsky ore junction, situated some 60 km ESE of Noril'sk. It appears significant that these ore junctions also occur at the edges of major sedimentary depositional basins. At Noril'sk, the mineralized bodies intrude continental sediments and the overlying basalts, whereas at Talnakh they intrude limestones and evaporates at a lower stratigraphic level. The vertical and horizontal dislocations, caused by the *en echelon* and variably oriented fault branches of the main rift