# LUNAR-TYPE PYROXENES IN TERRESTRIAL THOLEIITES?

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The complex and extreme chemical zoning in Lunar pyroxenes is well documented[1,2,3], the three principal variable components being Mg, Fe and Ca. The progressive Fe-enrichment from magnesian pyroxene cores to Mg-poor margins, to pyroxferroite in some cases, is often augmented by large changes in Ca content. In some instances Ca-poor pyroxenes are mantled by Ca-rich ones, and in others calcic cores have progressively Ca-poor margins. Oscillation in the precipitation of variably calcic phases together with the marked progressive increase in Fe content leads to "zig-zag zoning" (ZZZ) patterns, in terms of the Mg-Fe-Ca pyroxene quadrilateral components (Fig.1).

The most common pyroxene evolution trend in terrestrial rocks is a more modest, Skaergaard-type Fe-enrichment of calcic and Ca-poor phases (Fig.2). Cryptic chemical layering in large gabbroic intrusions is commonly reflected by the change in composition of the component pyroxenes (and other phases) from different levels within an intrusion, and thus they provide a measure of the large-scale differentiation of the magma body as a whole. However, detailed work on the composition of pyroxenes in

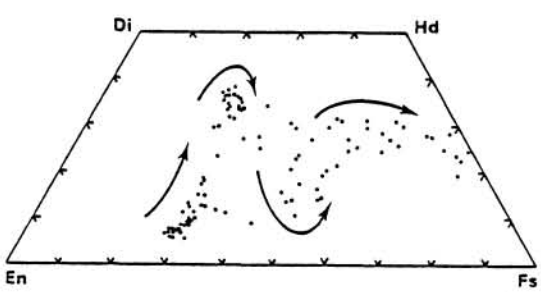


Fig.1. Chemical evolution of pyroxenes in Lunar sample 12065-112 (authors' data) in terms of Ca, Mg and Fe, showing a progressive overall Fe-enrichment and oscillatory Ca-enrichment and depletion, producing a zig-zag zoning (ZZZ) pattern with respect to these components.

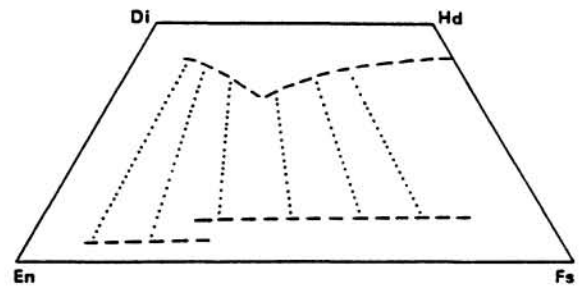


Fig.2. Schematic Skaergaard-type pyroxene evolution trend defined by samples from sequentially higher levels of a strongly differentiated intrusion. Pyroxene-pairs within individual samples (tie-lines shown as dotted lines4,5) tend to be relatively uniform.

hypabyssal mafic intrusions has revealed highly complex assemblages which appear to bear a closer resemblance to Lunar pyroxenes than they do to "normal" terrestrial ones.

Three main types of assemblage have been recognised (Fig.3). Type I comprises 1-, 2- or 3-pyroxene assemblages which have a relatively consistent Ca content (both calcic and Ca-poor) but vary greatly in Mg and Fe content. Type II pyroxenes vary mainly in Ca content but have a relatively constant ferrosilite component. Type III pyroxenes vary in Mg, Fe and Ca and largely plot in the "miscibility gap" compositional field in terms of these components. We emphasize that these pyroxene types are represented by individual complex grains in many cases.

There is no simple correlation between the pyroxene assemblage type and the bulk rock major element chemistry. For example, the Type II assemblages have been recognised in both Mg- and Fe-rich dikes, although they appear to occur most commonly in magnesian rocks. They have been described previously in komatiitic and boninitic lavas and they also occur in the intrusive noritic equivalents of boninites[6]. Plagioclase is

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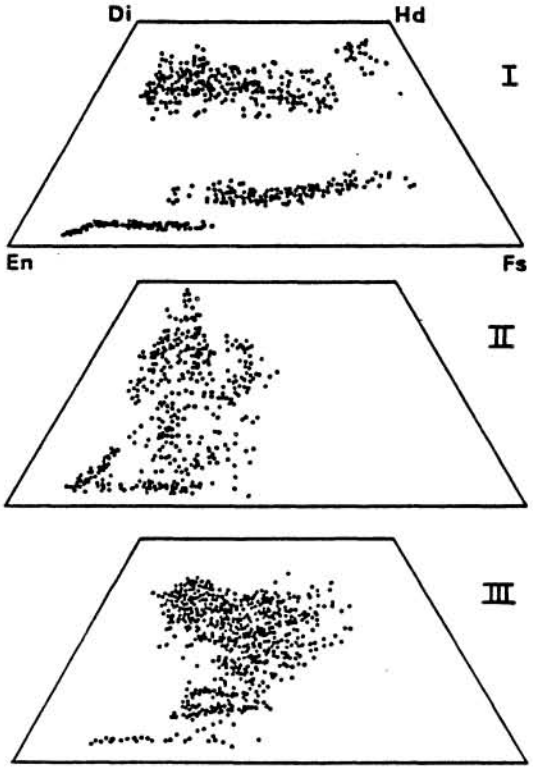


Fig.3. Types I, II and III pyroxene assemblages encountered in hypabyssal basic rocks (14, 10 and 14 samples respectively).
Type I: Skaergaard-type Fe-enrichment trend; individual grains define around half the trend.
Type II: Variably calcic clinopyroxenes (consistent Fs) and weakly zoned orthopyroxene.
Type III: variable Ca, Mg and Fe in clinopyroxene, Fe-enrichment in orthopyroxene.

characteristically late in the crystallisation sequence of these rocks. However, they also occur in plagioclase-phyric ferro-dolerites in West Greenland.

Type I pyroxene assemblages demonstrate marked Fe-enrichment, but the compositions of individual grains mimic around half of an entire Skaergaard-type pyroxene evolution trend in some instances, reflecting extreme (by terrestrial standards) differentiation of the tholeiitic liquid from which they were derived, on a sub-grain scale. This brings into question the emplacement and differentiation mechanisms and the rôle of, for example, gravitational settling in layered intrusions with respect to cryptic chemical layering[7]. Perhaps the only difference between these pyroxene assemblages and the "ZZZ" ones is that there was no periodic cessation in crystallisation of either the calcic or Ca-poor phases.

Type III pyroxenes appear at first sight to represent a combination of Types I and II, but in some cases, neither of these first two zoning trends can be identified in the Type III grains[8]. They may or may not reflect a combination of the crystallisation factors which effect Type I and II assemblages.

Our investigations of mafic hypabyssal intrusions suggest that complex pyroxene assemblages are the norm rather than the exception in tholeiitic bodies. One pre-requisite would seem to be a relatively low oxygen fugacity, commonly indicated by the composition and late-precipitation of the Fe-Ti oxide phase, which commonly appears to have been ulvospinel. This feature, of course, is demonstrated most clearly by Lunar assemblages.

*References*

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