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PETROCHEMICAL AND PETROPHYSICAL CHARACTERIZATION OF THE LOWER CRUST AND THE MOHO BENEATH THE WEST AFRICAN CRATON, BASED ON XENOLITHS FROM KIMBERLITES

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Notwithstanding the attention given over the past several decades to the genesis of the crust, interpretations of the nature of the continental lower crust remain diverse and opinions differ widely as to whether the lower crust is hydrated or anhydrous, and mafic or felsic. The present study attempts to constrain models of the lower crust and upper mantle through integration of petrochemical and petrophysical properties of a suite of granulites (garnet anorthosites to garnet pyroxenites) and eclogites from the Man Shield of the West African Craton. Age provinces in the shield are Leonean (~3.0 Ga), Liberian (~2.7 Ga), and Eburnean (~2.0 Ga), and these are fault bounded by the ~550 Ma Pan African age province. Crustal granulites and upper mantle eclogites were sampled as xenoliths from diamondiferous kimberlites of Cretaceous age (90-120 Ma) which were intruded into Liberian age province granitic gneisses in Liberia and Sierra Leone.

Most of the granulites are typical of those from elsewhere in Africa (1) and other world-wide locations (2), but some apparently differ in three significant respects: firstly in the presence of iron metal (3), secondly in the effects of metasomatism (4), and thirdly in aspects of partial melting. Native iron of low Ni and Co content, in association with scapolite and/or a highly aluminous (18-21 wt% Al_2O_3) tschermakitic amphibole, was formed by decomposition of almandine-rich ($Alm_{51-56}Pyr_{27-32}Gross_{14-17}$) garnet. Iron metal also resulted from ilmenite decomposition in which iron, ulvöspinel, troilite, and FeTiS were formed. Temperature estimates are 830-1000°C at fO_2's at or below iron-wüstite (IW). Metasomatism is manifest in the formation of scapolite (60-75 % Me), and also in rims of ferro-freudenbergite ($Na_2FeTi_7O_{16}$) around nucleii of rutile, a reaction in which ilmenite, perovskite, and sphene were also formed (4). Metasomatic fluids or partial melts were enriched in Na, Fe, Ca, and Si in contrast to those typical of upper mantle metasomatism in which metasomatic enrichment is characterized by K, Ba, Sr, Ti, LREE, Nb, and Zr (5). Partial melting of the granulites, specifically of garnet and plagioclase, yielded clinopyroxene + kyanite + scapolite. A characteristic feature of these classes of granulites is the presence of graphite.

Major element XRF analyses, petrographic and electron microbeam mineral chemistries, densities, magnetic properties, and calculated P-T and seismic P-wave velocities (V_p) have been determined for most of the larger specimens of granulite, and for selected eclogites and anorthosites. A chemical continuum between these lithologies has been established (Fig. 1). High Mg eclogites, approaching komatiitic basalts in composition, grade progressively into low Mg eclogites (of alkali hawaiite affinity), granulites (of high alumina alkali basalt composition), and garnet anorthosites. For these xenoliths, specific gravity (SG) is directly proportional to FeO + MgO and inversely proportional to alkalies and to SiO_2. Seismic P-wave velocities for the low Mg eclogites and the granulites, estimated from SG (6), show a range from 6.6 to 8.7 km/sec with a transitional group between typical crustal and mantle values which is comprised of both lithologies (Fig. 2). Magnetic susceptibilities and NRM values of the granulites are shown as functions of SG, wt% FeO, and wt% SiO_2 in Fig. 3; assuming that V_p, SG, and FeO increase and SiO2 decreases with depth then the induced and remanent magnetizations increase in intensity within the lower crust (7). Ferromagnetism may persist within the upper mantle to 90 km depth (3), or to shallower depths (~70 km) if upper mantle metasomatism induces relatively oxidized horizons (8). P-T estimates and a geothermal gradient derived for the eclogites and granulites (9) lie between the gradients commonly assumed for cratonic surface heat flows (~40 mW/m^2) and typical rift environments (~90 mW/m^2).

Granulites, eclogites, and garnet anorthosite xenoliths from the West African Craton appear to be petrologically, geochemically, and geophysically related, although some show evidence of subsolidus reduction and decomposition, metasomatism, and partial melting. The continuum in bulk chemistry and P-wave velocity strongly implies that the lower crust - upper mantle boundary between 40 and 70 km (Fig. 2) is not a simple petrological discontinuity but is instead at least in part an intercalated granulite-eclogite transition zone that may have resulted from igneous fractionation, metamorphism, and partial melt underplating in a developing continental lithosphere. From diamond inclusion evidence, the subcratonic lithosphere is dominantly ultramafic and is inferred to be at least 200 km thick and Archean in age, an age in accord with the oldest surface rocks of the West African Craton. Felsic rocks form a minor component of the lower crust of this craton, and hydrated mineralogies are clearly superimposed or are the by-product of re-equilibration. Hence the continental lower crust of the Man Shield is dominantly anhydrous, mafic, and reduced in redox state.

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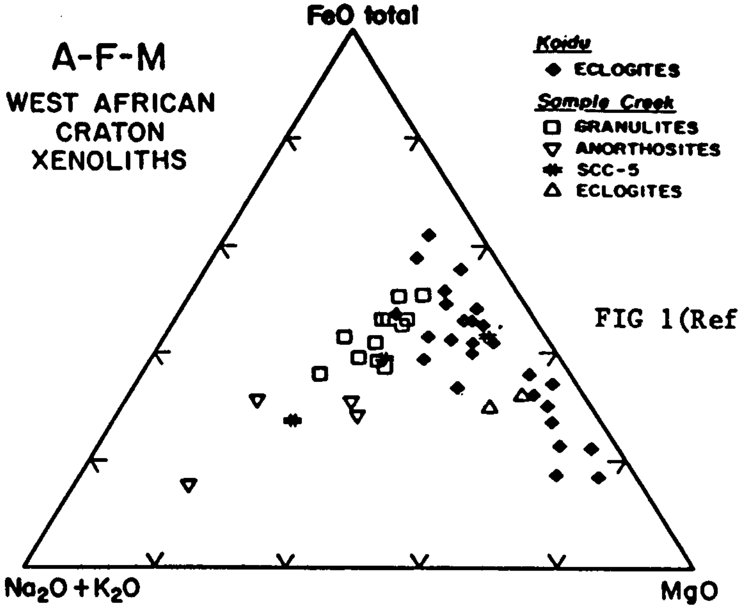

FIG 1(Ref.9)

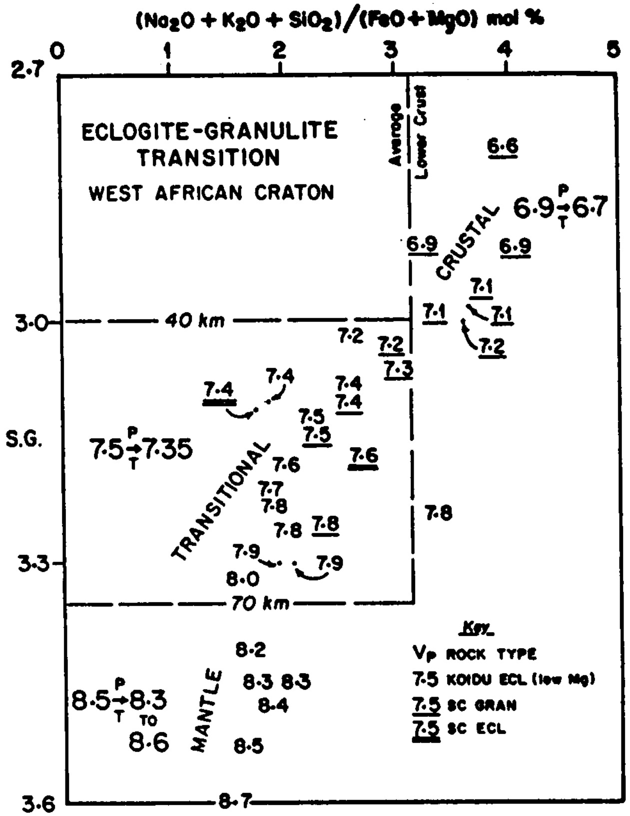

FIG 2(Ref.9)

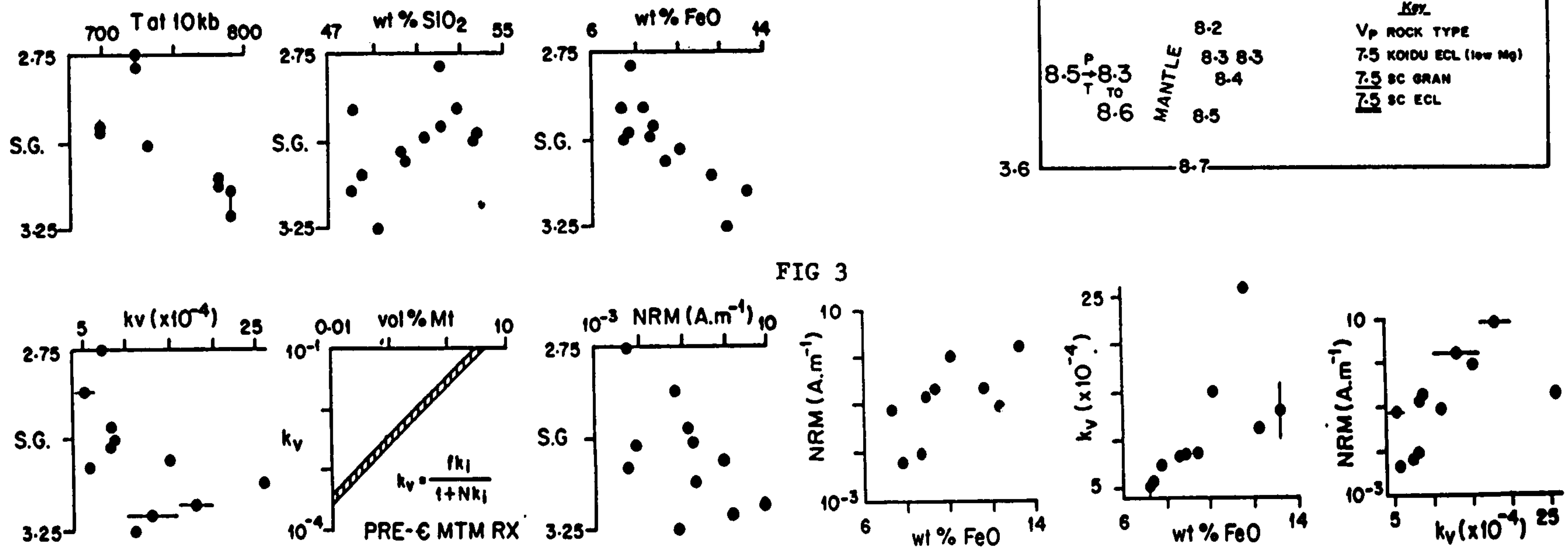

FIG 3