CHAPTER – IV

PETROGRAPHY

IV.1 Introduction:

Owing to their complex and hybrid nature, kimberlites display a prominent and typical inequigranular texture wherein large rounded-to-anhedral crystals are found set in a fine-grained matrix. While some of these large grains are xenocrysts, others may be phenocrysts or xenocrysts. The origin of these large single crystals has remained a mystery and their origin remains unanswered. The large (1-20 cm) single crystals corresponding to compositions of magnesian ilmenite, Cr-poor titanian pyrope garnet, sub-calcic diopside, enstatite, phlogopite, zircon etc have been regarded as discrete nodule suite by Boyd and Nixon (1973) and opine that these large single crystals are unconnected to kimberlite and are xenocrysts, derived from the “crystal mush magma”. Thus xenocrysts, simply refer to the crystals, are alien and unrelated to the magmatic liquid. Such phenocrystal phases, are referred to as megacrysts and macrocrysts – devoid of genetic references. Looking at the complexities involved in the terminologies, Mitchell (1986, 1995) provided a plausible solution by giving the following definitions to the various terminologies employed in describing the kimberlites petrography:

- Megacrysts are large (1-20 cm) rounded to anhedral single crystals of magnesian ilmenite, Cr-poor titanian pyrope, Cr-rich diopside, enstatite, phlogopite and zircon. Kimberlites with >5 vol% of such crystals be described as megacrystal kimberlites.
- Macrocrysrs are rounded to anhedral crystals (primarily olivine) measuring 0.5 – 10 mm in their maximum dimension and kimberlites with > 5 vol% of these crystals are termed as macocrystal kimberlites.
- Micocrysts are small (<0.5 mm, commonly 1- 500 µm), anhedral crystals, which are compositionally similar to megacrysts and macrocrysts, and they are interpreted as fragments of megacrysts and macrocrysts.
• Euhedral to sub-hedral crystals measuring 0.1 – 0.5 mm are microphenocrysts and the similar grains, measuring > 0.5 mm, are phenocrysts. They are the products of crystallization of the magma.

• The megacryst, macrocryst, microcryst and phenocryst assemblage together with the xenoliths and autoliths are all set in a very fine-grained to optically unresolvable matrix.

The textural features exhibited by kimberlites depend upon the facies to which the particular exposure belongs.

The diatreme facies, for instance are distinguished by fragmental nature resulting from the presence of angular to rounded country rock fragments, that admeasure from a few centimeters to sub-microscopic sized autoliths (rounded fragments of earlier generations of kimberlite), pelletal lapilli, nuleated autoliths fragmented mantle xenoliths, discrete and fractured grains of olivine, garnet and ilmenite megacrysts and macrocrysts set in a product of magmatic crystallization consisting of microphenocrysts and groundmass. The matrix supporting the pelletal lapilli, autolithic and xenolithic clasts is constituted by diopside and serpentine (when fresh) and occasionally by phlogopite (Mitchell, 1986). The outstanding feature of the matrix is that all of the crystals are extremely fine grained or cryptocrystalline and in general are devoid of normal igneous granular or poikilitic textures. The matrix may be uniform or may show discrete segregations of serpentine and diopside. The continuity of diatreme facies sometimes may exceed 2 km in depth.

The hypabyssal facies kimberlites on the other hand megascopically distinctive by being massive rocks with pronounced by igneous textures and consisting of macrocryst represented mostly by olivine and sometimes by ilmenite, phlogopite, garnet etc that are commonly visible. The visible igneous textures are the result of magmatic differentiation. Some of the characteristic textural features of this facies include: 1) absence of pyroclastic fragments and textures, 2)
presence late stage poikilitic growth of phlogopite and 3) textures involving segregation of calcite and serpentine.

IV.2 Petrography of the Kalyandurg Kimberlites:

The Kalyandurg kimberlites are marked by distinctive inequigranular and brecciated texture wherein large rounded macrocrysts (represented by olivine, ilmenite and garnet) along with auto-liths and xenoliths of crustal and mantle origin in a fine-grained groundmass. The groundmass minerals include euhedral to subhedral microphenocrysts constituted by olivine, perovskite, serpentine, monticellite and rarely diopside and phlogopite. Opaques are mainly ilmenite, magnetite and chromite. Perovskite is mostly associated with opaques. Both the macrocrystal and microphenocrystal olivine get completely replaced by serpentine and calcite. It is pertinent to mention that the petrological descriptions of kimberlites modal abundances determined on single thin sections carry little significance and it is therefore in this context, in the following paragraph description of the textures of the Kalyandurg kimberlites is made, following the textural and mineralogical classification of Mitchell (1986) on the basis of observed generalizations on many thin sections from each pipe.

i) Pipe KL-1: This kimberlite of Kalyandurg is a highly weathered and altered body and exhibits a greenish grey colour in hand specimens. The alteration is persistent even up to 90 m depth as observed from the drill samples. Despite the high degree of alteration and weathering, the kimberlite body exhibits a typical inequigranular texture with pseudomorphs of large rounded olivine grains set in a fine-grained groundmass. Under microscope, KL-1 displays macrocrystal, brecciated texture that are dominated by heterolithic clasts (>20%) measuring >4 mm and macrocrysts of olivine and ilmenite (10 – 15%) set in a fine-grained groundmass composed of smaller (0.1 – 0.5 mm) euhedral to subhedral olivine, perovskite, ilmenite, serpentine and phlogopite (Fig. IV-1). The macrocrysts include pseudomorphs of large rounded anhedral olivine measuring up to 1.5 cm, and ilmenite. Olivine is thoroughly serpentinised and even replaced by calcite. It exhibits undulose extinction and at several places are seen carrying inclusions
of diopside, ilmenite and phlogopite. Both olivine and ilmenite macrocrysts reveal the effects of corrosion. Microcrysts of olivine and ilmenite too are anhedral but measure <0.5 mm. Perovskite is noticed as rounded, stubby brownish grains and distinguishes itself with a high relief. Lithic fragments include angular fragments and corresponding to granitic composition of variable dimensions are prominently noticed in this body. At few places of the kimberlite body, the granite clasts constitute up to 50 – 60% of the rock. Autoliths, which are fragments of earlier generation kimberlite, occur as rounded clasts measuring up to 1 – 2 cm (Fig.IV-1). These autoliths are relatively richer in phlogopite compared to the host kimberlite.

![Macrocrystal texture in pipe KL -1](image)

**Fig. IV-1:** Macrocrystal texture in pipe KL -1. Large anhedral macrocrysts of olivine (O), Ilmenite (I) and Kimberlite autolith (Au), Crustal xenoliths (C) and smaller euhedral olivine (ol), Ilmenite and perovskite set in a very fine-grained groundmass rich in serpentine (S). Note the autolith is richer in phlogopite (P). The macrocrysts are altered to serpentine and calcite. In some cases phlogopite is developed as a result of alteration of the olivine.

**Pipe KL -2:** This kimberlite also is a highly weathered and altered body, and is seen with a greenish grey colour in hand specimens. This alteration is seen even up to a depth of 90 m as observed in the drilling sites and also from the collected drill samples. In hand specimens and drill samples the body exhibits a typical inequigranular texture with pseudomorphs of large rounded olivine grains set in a fine-
grained groundmass. In thin sections, it exhibits macrocrystal, brecciated texture and is supported by the presence of 5-10% heterolithic clasts ( > 4 mm), macrocrysts of garnet (~1.5 cm) and 20 – 30 % macrocrysts of olivine and ilmenite and smaller (<0.5 mm) anhedral microcrysts of olivine and ilmenite set in a fine grained groundmass, that is constituted by smaller (0.1 – 0.5 mm) euhedral to subhedral olivine, perovskite, ilmenite and serpentine (Figs. IV-2 to IV-5). The body also exhibits a pelletal lapilli texture (Fig.IV-2 & IV-5) with pseudomorphs of large olivine occurring as nucleus. The macrocrysts include large rounded to anhedral olivine measuring 3 – 4 cm, and ilmenite, which show effects of corrosion. Olivine is thoroughly serpentinised and even replaced by secondary calcite. Olivine macrocrysts exhibit undulose extinction and contain inclusions of diopside, ilmenite and phlogopite. The garnet occurs as large ~ 2 cm rounded isotropic grains with a high relief. Garnets invariably have a reaction rim of kelyphite (Figs. IV-5), which consists of extremely fine-grained phyllosilicates. Perovskite occur as rounded stubby grayish brown grains with a high relief. A few phlogopite grains are seen in the groundmass. Occasionally, phlogopite is also noticed as replacing some of the olivine macrocrysts and also microphenocrysts. Lithic fragments include angular fragments of granite of varying dimensions ranging from sub-microscopic to 2 – 3 cm and mantle xenoliths 95% of which are eclogites.
Fig. IV - 2: Macrocrystal texture in pipe KL -2. Large sub-hedral and anhedral olivine macrocrysts (O) and euhedral to subhedral microphenocrysts of olivine (ol) in a serpentine (S) rich groundmass. Note development of phlogopite (P) along the rim and fractures of some of the olivine microphenocrysts.

Fig. IV - 3: Macrocrystal texture in pipe KL -2. Large subhedral to anhedral olivine macrocrysts (O) and subhedral to euhedral olivine microphenocrysts (ol), ilmenite (I) in a serpentine (S) rich groundmass. Phlogopite is seen as anhedral grains (P) within groundmass. Olivine macrocrysts altered to serpentine (s), Spinel (Sp) and calcite (c) are also observed.
Fig. IV- 4 : Macrocystal texture in pipe KL -2. Large subhedral to anhedral olivine macrocrysts (O) and subhedral to euhehedral olivine microphenocrysts (ol), ilmenite (I) in a serpentine (S) rich groundmass. Phlogopite is seen as anhedral grains (P) within groundmass. Olivine macrocrysts altered to serpentine (s) and calcite (c).

Fig. IV - 5 : Macrocystal texture in pipe KL -2 showing crustal xenoliths (CX). Macrocysts of olivine (O) and garnet (G) and microphenocrysts of olivine (ol) perovskite (P) set in a groundmass of predominantly serpentine. The garnet grain is with kelyphite rim.

Pipe KL -3 : This body distinguishes from the others with a profuse a calcrete capping and this KL-3 body occurs a few melanocratic hard
outcrops with a greenish black colour in hand specimens. The body exhibits a typical inequigranular texture with serpentinised pseudomorphs of large rounded olivine grains set in a fine-grained groundmass. In thin sections it exhibits macrocrystal, brecciated texture with 5 – 10% heterolithic clasts measuring > 4 mm and > 20% macrocrysts of olivine and ilmenite set in a fine grained groundmass composed of smaller (0.1 0.5 mm) euhedral to subhedral olivine, perovskite, ilmenite and phlogopite in amatrix predominatly composed of serpentine (Fig.IV - 6).

Fig. IV – 6: Macrocrysal texture in pipe KL – 3. Large anhedral macrocrysts of olivine (O) and microphenocrysts of olivine (ol), perovskite (p), Spinel (Sp), phlogopite (P – brown coloured material) in a groundmass of predominantly serpentine and ilmenite (I). Note the corroded margins of the macrocrysts of occupied mostly by ilminte.
Fig. IV – 7: Macrocystal texture in KL – 3. Macrocysts of Olivine (O) & Garnet (G) and microphenocrysts of olivine (ol), perovskite (P) and brown coloured phlogopite set in a groundmass of predominantly serpentine & microphenocrysts of ilmenite.

Fig. IV – 8: Macrocystal texture in pipe KL – 3. Macrocysts of olivine (O) and microphenocrysts of olivine (ol) set in a groundmass of predominantly serpentine and ilmenite (il) (PPL).
In some thin sections, phlogopite is noticed as late stage poikilitic growth enclosing the smaller opaque crystals (Fig.IV-6). The macrocrysts include pseudomorphs of large rounded anhedral olivine measuring up to 1.5 cm, ilmenite and spinel measuring ~0.5 mm. Olivine is thoroughly serpentinised and even replaced by secondary calcite and the rim portion is occupied by opaque minerals (magnetite & ilmenite). It exhibits undulose extinction and inclusions of diopside, ilmenite and phlogopite. Both olivine and ilmenite macrocrysts show effects of corrosion. Spinel occurs as subhedral grains with deep red colour (Fig. IV-6). Microcrysts of olivine and ilmenite too are anhedral but measure < 0.5 mm. Perovskite occurs as rounded stubby brownish grains with a high relief. Lithic fragments include angular fragments of granite varying dimensions ranging from sub-microscopic to 2 -3 cm. In certain parts of the kimberlite the granite clasts constitute up to 20-30% of the rock. Autoliths, which are fragments of earlier generation kimberlite, occur as rounded clasts measuring up to 3 - 4 cm (Fig. IV-9). These autoliths are relatively richer in phlogopite compared to the host kimberlite. Mantle xenoliths are relatively richer in phlogopite.
compared to the host kimberlite. All thin sections of KL-3 are shown Fig.IV-6 to Fig.IV-10a).

Fig. IV – 9: Macrocrystal textutre in pipe KL-3. Large anhedral to subhedral macrocrysts of olivine (O) and microphenocrysts of olivine (ol), cacite (C), spinel (Sp), phlogopite (P) and perovskite (p) in a groundmass of predominantly serpentine and ilmenite (I). **Note Within Red Colour polygon**: Kimberlite Autolith in a uniform groundmass. Margins of the Autolith are diffused. The higher content of Phlogopite in the autolith than in the surrounding kimberlite.

Fig. IV – 10: Garnet in KL – 3 (PPL).
Pipe KL - 4: This kimberlite is also a weathered and is by and large altered body with few unaltered hard outcrops which exhibit a greenish black colour in hand specimens. This melanocratic body displays a typical inequigranular texture with pseudomorphs of large rounded olivine grains that are set in a fine-grained groundmass. Under microscope, it reveals macrocrystal, brecciated texture with >10% heterolithic clasts measuring > 4 mm and >10% macrocrysts and microcrysts of olivine and ilmenite set in a fine-grained groundmass composed of smaller (0.1 – 0.5 mm) euhedral olivine, perovskite, ilmenite in a groundmass composed of serpentine and monticellite (Fig. IV-11,12 & 13). The KL-4, is marked by an occasional segregation of diopside in the groundmass phase. Minor amounts of apatite with colourless prismatic crystals exhibiting high relief also occur in the groundmass phase (Fig. IV-11). In this kimberlite body, occasionally macrocrysts of garnet are also noticed. These garnets are rounded grains admeasuring 2.5 – 3.0 cm have a high relief and kelpite rim measuring up to 0.3 mm in width (Fig. IV-12 &13). The thin sections of KL-4 are shown from Fig.IV-11 to Fig.IV-17.
Fig. IV – 11: Macrocrystal kimberlite breccia in pipe KL-4. Note angular crustal xenolith fragments (CX) & macrocrysts of Garnet (G). Two populations of olivine (Macrocrysts & microphenocrysts), Phlogopite (P), ilmenite (I) and serpentine (S). The olivine macrocrysts have a rim of serpentine (S).

Fig. IV -12: Garnet xenocryst surrounded by microphenocrysts of olivine (ol) set in a groundmass of predominantly serpentine and ilmenite (I) in KL-4. Note the kelpite rim (dark coloured) around the garnet grain (G). Two populations of olivine, i.e., Macrocryst of olivine (O) and microphenocrysts of olivine (ol) (PPL).
Fig. IV - 13: Garnet xenocryst surrounded by microphenocrysts of olivine (ol) set in a groundmass of predominantly serpentine and ilmenite (I) in KL-4. Note the kelphite rim (dark coloured) around the garnet grain (G). Two populations of olivine, i.e., Macrocryst of olivine (O) and microphenocrysts of olivine (ol) (XPL).

Fig. IV – 14: Macrocrystal texture in pipe KL – 4. Large sub-hedral olivine macrocryst (O) and euhedral to subhedral microphenocrysts of olivine (ol) in a serpentine (S) and ilmenite (I) (PPL).
Fig. IV – 15: Macrocystal texture in pipe KL – 4. Large sub-hedral olivine macrocryst (O) and euhedral to subhedral microphenocrysts of olivine (ol) in a serpentine (S) and ilmenite (I) (XPL).

Fig. IV-16: Segregation texture in pipe KL – 4. Segregation include serpentine (S), Phlogopite (P) and opaques. Note the late stage poikilitic growth of phlogopite enclosing the opaques.
Pipe KL – 5 & 6: These kimberlites are also weathered and altered bodies to a small extent with a few melanocratic hard outcrops with a greenish black colour in hand specimens. The body exhibits a typical inequigranular texture with pseudomorphs of large rounded olivine grains set in a fine-grained groundmass. In thin sections it exhibits macrocrystal, brecciated texture with >10% heterolithic clasts measuring > 4 mm and >10% macrocrysts and microcrysts of olivine and ilmenite set in a fine-grained groundmass composed of smaller (0.1 – 0.5 mm) euhedral olivine, perovskite, Ilmenite in a groundmass composed of serpentinite (Fig. IV-18 & 19). Fragmented calcite (primary) is seen floating in serpentine matrix in some of the thin sections. Large crustal xenolith of granitoid gneiss set in a kimberlite with microphenocrysts of olivine, phlogopite and some dark opaque minerals (Fig. IV-20).
Fig. IV – 18: Macrocystal kimberlite breccia pipe KL - 5. Angular crustal xenolith fragments (CX), Olivine macrocrysts and subhedral microphenocrysts of olivine (ol) and other opaque minerals (PPL).

Fig. IV – 19: Macrocystal kimberlite breccia pipe KL - 5. Angular crustal xenolith fragments (CX), Olivine macrocrysts and subhedral microphenocrysts of olivine (ol) and other opaque minerals (XPL).
Fig. IV – 20: Xenolith of granitoid gneiss in Kimberlite pipe KL – 5. Two populations of olivines, serpentine (S), ilmenites (I) and phlogopite (P).

The macrocrysts include pseudomorphs of large rounded anhedral olivine measuring up to 1.5 cm and ilmenite. Olivine is thoroughly serpentinised, corroded and replaced by secondary calcite. It exhibits undulose extinction and carries inclusions of ilmenite and phlogopite. Phlogopite is noticed at few places, replacing the olivine in some of the thin sections (Figs. IV-14 & 15) and also as late stage poikilitic growth (Fig. IV-16). Microcrysts of olivine and ilmenite also are anhedral but measure < 0.5 mm. Autoliths, which are fragments of earlier generation kimberlite, occur as rounded clasts measuring up to 2 – 3 cm (Fig. IV-16). It can be seen from the Fig. IV-16 that these autoliths are relatively richer in opaque minerals compared to the host kimberlite. Some of the thin sections also show strained phlogopite macrocrysts with bent flakes with development of opaque minerals along their margins (Figs. IV-17).

Magnesian olivine (forsterite) is the ubiquitous mineral phase present in all the four kimberlites. It occurs as sub rounded anhedral macrocrysts (0.5 – 10 mm) and as euhedral to subhedral microphenocrysts (~0.5 mm) in the groundmass associated with
phlogopite, perovskite and serpentine. Some of the grains exhibit undulose extinction and contain inclusions of garnet, diopside, ilmenite and phlogopite. The other minerals found in these kimberlites include macrocrysts of pyrope garnet, magnesian ilmenite, chrome rich spinels and chrome rich diopside set in the groundmass mineral phases like serpentine, perovskite, ilmenite, magnetite and rarely apatite. The macrocrysts may consist of resorbed megacrysts and xenocrysts (those derived from disaggregation of ultramafic xenoliths). Petrographically it is difficult to distinguish between the megacryst suite (discrete nodules) and the xenocryst populations of the different minerals. Pipes KL – 1 and KL -3 are relatively rich in phlogopite (up to 10% of the rock) all in the groundmass phase.

IV – 3: Petrography of the Timmasamudram Kimberlites:

TK-1: This kimberlite body at Timmasamudram is a weathered and altered one, emplaced in a TTG suite of rocks, and no concrete surface evidences were found and body has been identified by GSI in a pit and the body is profusely covered by thick soil cover, perhaps hiding weathered kimberlite body.

TK-2: Even this body identified by GSI, has no evidence of exposures and only after a thorough search by the research candidate few samples of kimberlite could be collected, which showed the signatures alteration. The kimberlite though weathered and altered to certain extent, typical inequigranular texture with phenocrysts of olivines and phlogopites, set in a fine grained ground mass could be noticed. It is very difficult to exactly pinpoint the % of heterolithic clasts, micro and macrocrysts in view of the altered nature of the body. However, it is pertinent to mention that flow structure (fig ) shown by macrocrysts and opaque minerals clearly establishes the hypabyssal nature of kimberlite body. TK-2

TK-3: This kimberlite body is also highly weathered and the nonavailability of the good sample does not allow the preparation of thin section. However the with available section it has been noticed that this macrocrystal kimberlite breccias pipe TK – 3 , has well preserved olivine macrocrysts (O) that are surrounded by a fine grained matrix
composed of subhedral microphenocrysts of olivine (ol) and microphenocrysts of other opaque minerals. In addition, the angular crustal xenolith fragments (CX) derived from the surrounding country rock also have been retained.

**Tk-4**: The Timmasamudram kimberlite body possesses inequigranular, pseudoporphiritic texture. In addition they carry crustal xenoliths of granitoid gneisses and amphibolites. The TK-4 kimberlites contain predominantly large rounded serpentinised and carbonated macrocrysts and microphenocrysts of olivine (three populations) and macrocrysts of enstatite, subcalcic diopside and phlogopite that are again set in a fine grained groundmass that is thoroughly serpentinised and carbonated and rich in phlogopite, perovskite and opaque mineral phases. A closer petrographic examination reveals the presence of different varieties of phlogopite mica. The olivine macrocrysts carry tiny, needle shape inclusions. Two pulses of kimberlites are observed; fragments of earlier brownish kimberlite floating in the later greenish variety.

![Image](image-url)

Fig. IV – 21: Macrocrysts of phlogopites surrounded by microphenocrysts of groundmass mica in kimberlite pipe TK – 2.
Fig. IV – 22: Flow structure shown by macrocrysts and opaque minerals indicating hypabyssal nature of kimberlite pipe – TK-2.

Fig. IV – 23: Macrocystal kimberlite breccias pipe TK - 3. Angular crustal xenolith fragments (CX), Olivine macrocrysts (O) and subhedral microphenocrysts of olivine (ol) and microphenocrysts of other opaque minerals.
Fig. IV-24: Flow structure shown by macrocrysts and opaque minerals indicating hypabyssal nature of kimberlite pipe – TK-4 (PPL).

Fig. IV-25: Flow structure shown by macrocrysts and opaque minerals indicating hypabyssal nature of kimberlite pipe – TK-4 (XPL).
Fig. IV–26: Two populations of olivines (macrocrysts and microphenocrysts) set in a groundmass rich in serpentine and microphenocrysts of ilmenite in kimberlite TK–4. Corroded margins of the macrocrysts occupied by phlogopite (P) and ilmenite.

Fig. IV–27: Two generations of olivines (macrocrysts and microphenocrysts) surrounded by microphenocrysts of ilmenites and phlogopites set in a groundmass occupied by serpentene in kimberlite TK – 4. Macrocrysts of olivine margins occupied by serpentene.
Fig. IV – 28: Two populations of olivines (macrocrystal & microphenocrystal) surrounded by serpentine and microphenocrysts of opaque minerals in kimberlite pipe TK - 4.

Fig. IV – 29: Xenolith of Amphibolite in kimberlite pipe TK – 4.

It can be broadly stated that petrographically the Kalyanadurg and Timmasamudram kimberlites, with around 10 -15% xenoliths, > 15% macrocrysts and microcrysts and exhibiting a brecciated texture
and therefore the Kalyandurg and Timmasamudram kimberlites can be termed as macrocrystal heterolithic kimberlite breccia. Mineralogically, these kimberlites can be classified as monticellite – serpentine kimberlite, calcite-serpentine kimberlite, phlogopite-serpentine kimberlite and diopside-serpentine kimberlite. Texturally and mineralogically they are well comparable with the kimberlite of the WKF. Textural features such as fragmented nature, total absence of pyroclastic fragments, presence of autoliths, discrete and fractured grains of olivine, late stage poikilitic phlogopite, segregation textures involving segregation of calcite and serpentine qualify the Kalyandurg and Timmasamudram kimberlites to be categorized as belonging to hypabyssal facies kimberlites transitional to diatreme facies.

************