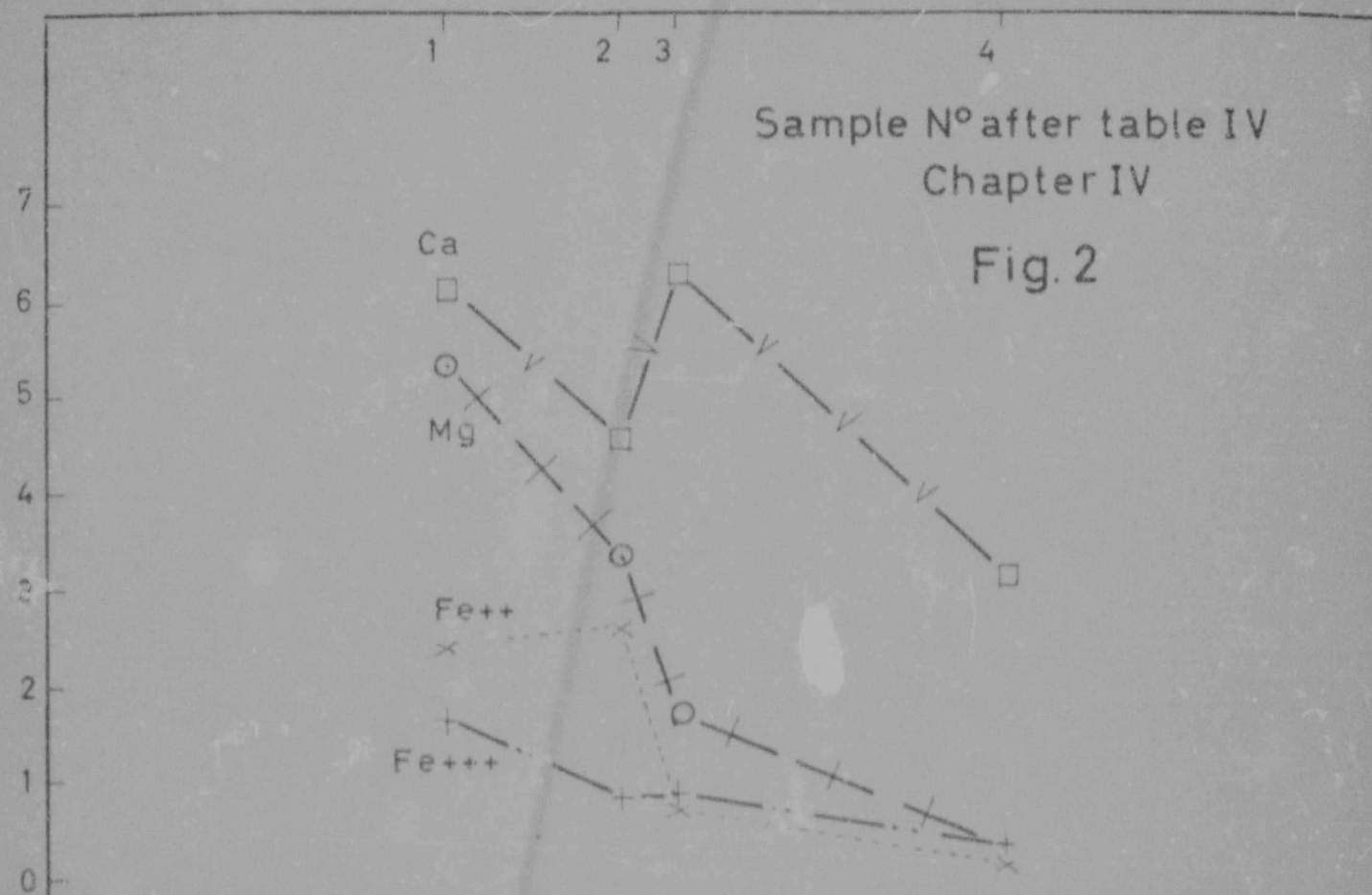


(v).- Grey granitic rocks (modal analysis giveⁿ₂ in sample 3 of table III).
Upper Hlimbitwa river.

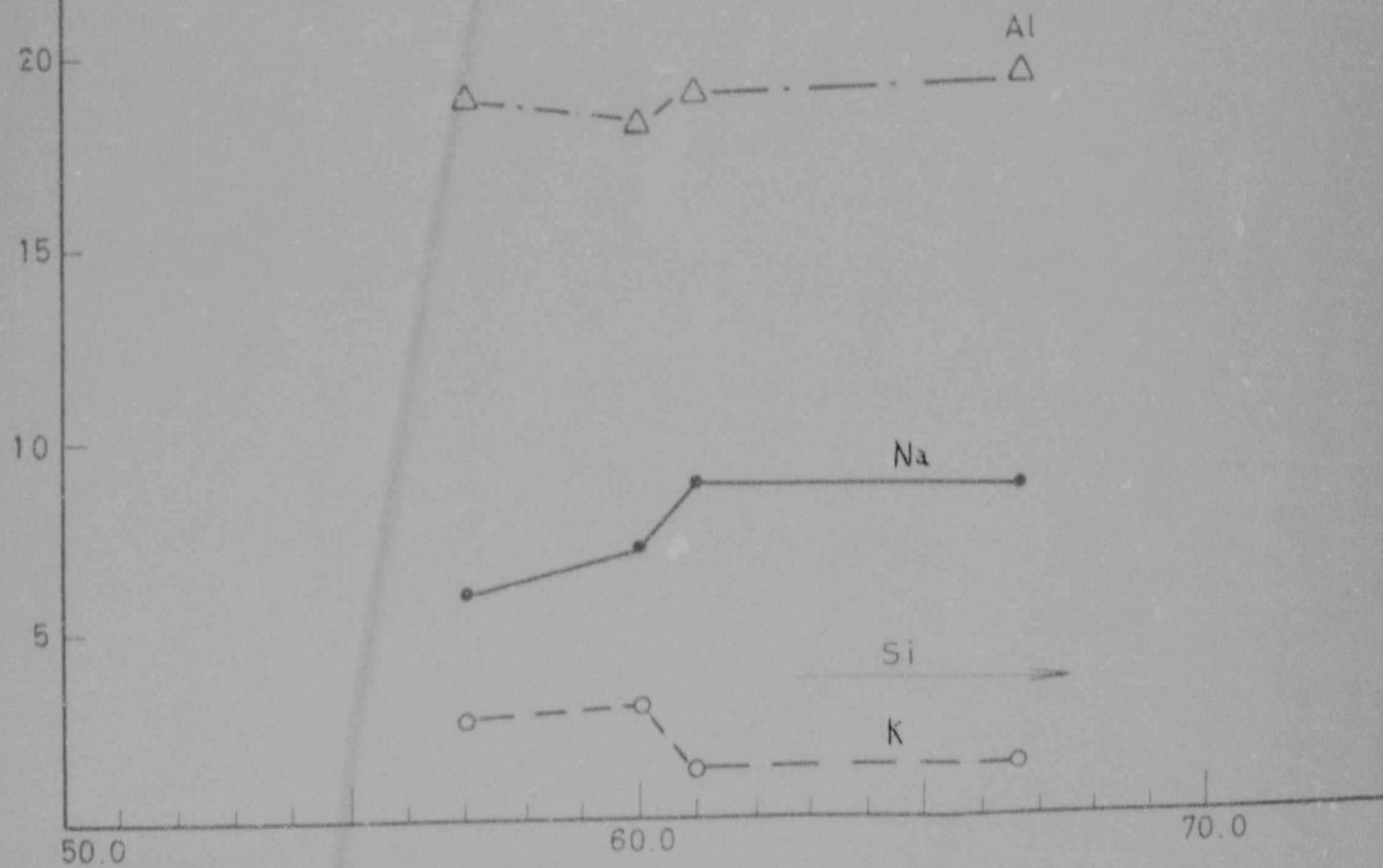
	Weight	Cation	<u>Niggli Values</u>		<u>Norm</u>
	<u>%</u>	<u>%</u>			
SiO ₂	68.78	64.3	si	308	llm = 0.4
Al ₂ O ₃	15.80	17.4	k	0.26	Or = 15.0
Fe ₂ O ₃	1.27	0.9	mg	0.50	Ab = 43.5
FeO	0.97	0.7			An = 14.3
CaO	1.18	1.7	al	43	Mt = 1.4
MgO	3.06	3.1	fm	14	Wo = 0.3
Na ₂ O	4.76	8.7	c	14	Ens = 3.4
K ₂ O	2.54	3.0	alk	29	Fs = 0.1
TiO ₂	0.30	0.2		100	Qz = 21.6
H ₂ O+	0.65				100.0
H ₂ O-	0.28				
Total	99.59	100.0			

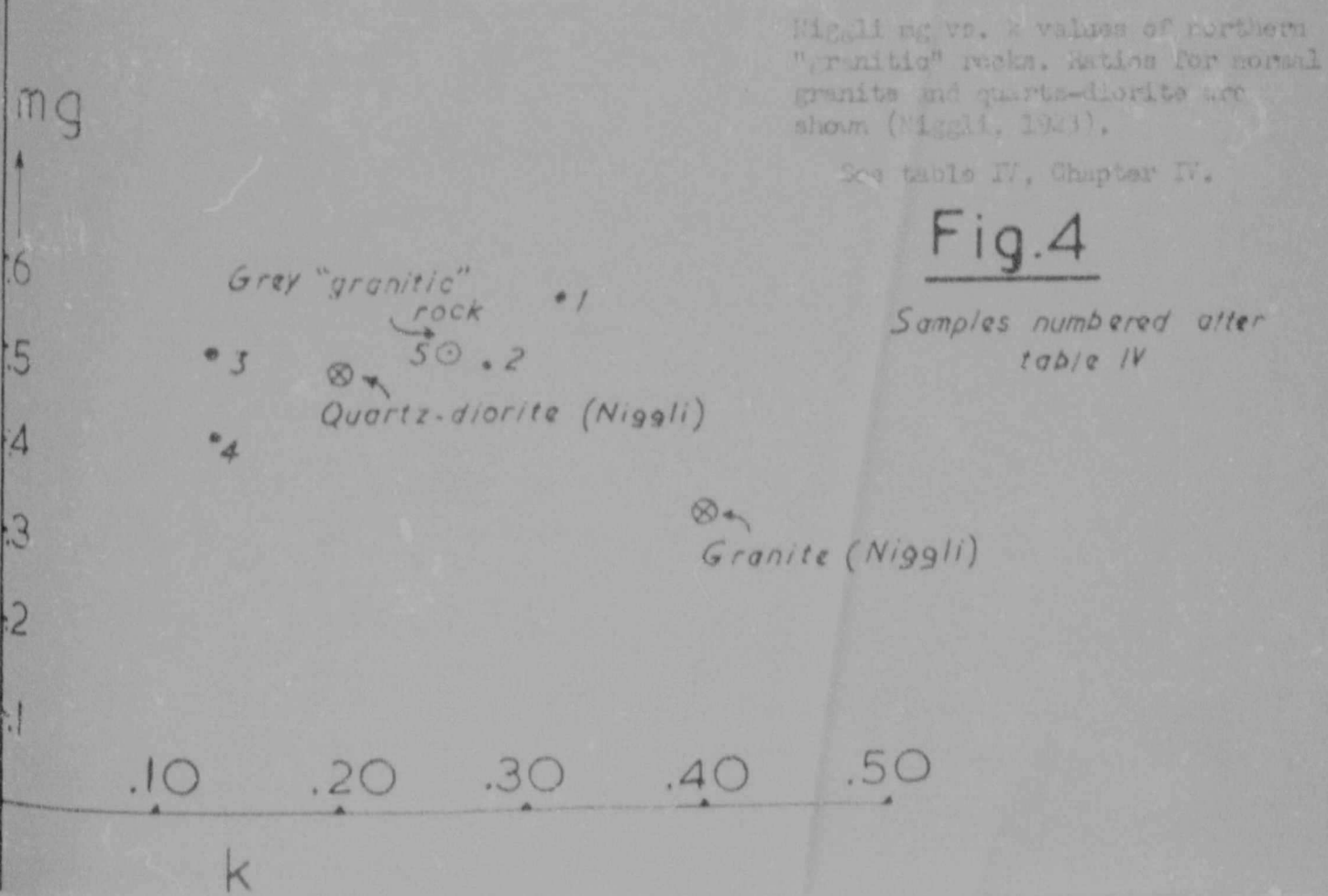
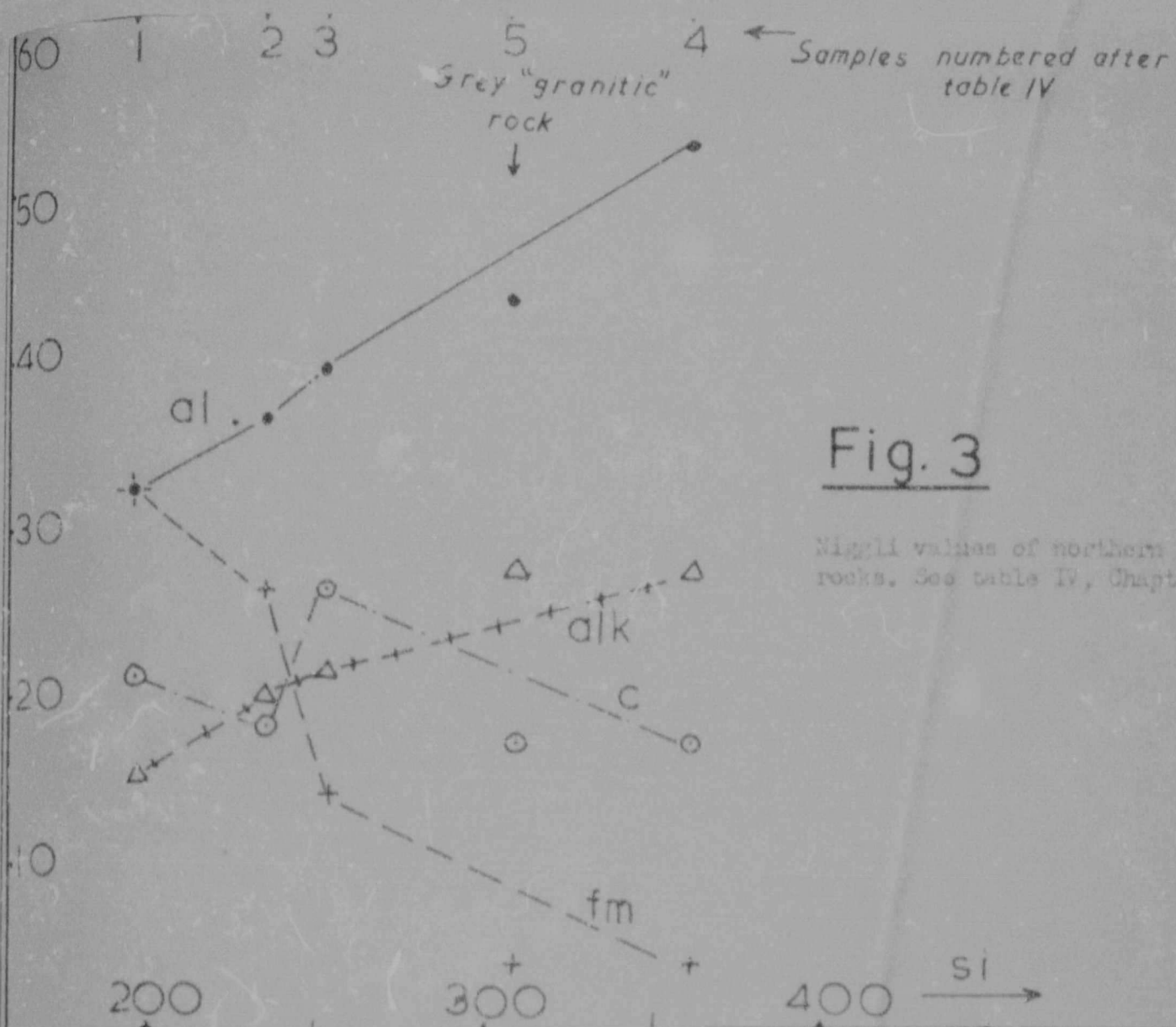
(v).- Grey granitic rocks (modal analysis giveⁿ_A in sample 3 of table III).
Upper Hlimbitwa river.

	Weight	Cation	Niggli Values		Norm
	<u>%</u>	<u>%</u>			
SiO ₂	68.78	64.3	si	308	llm = 0.4
Al ₂ O ₃	15.80	17.4	l	0.26	Or = 15.0
Fe ₂ O ₃	1.27	0.9	mg	0.50	Ab = 43.5
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CaO	1.18	1.7	al	43	Mt = 1.4
MgO	3.06	3.1	fm	14	Wo = 0.3
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K ₂ O	2.54	3.0	alk	29	Fs = 0.1
TiO ₂	0.30	0.2		100	Qz = 21.6
H ₂ O+	0.65				100.0
H ₂ O-	0.28				
Total	99.59	100.0			



Cation percentages of various elements, plotted against
cation percentage of silicon in northern "granitic" rocks.
See table IV, Chapter IV.





The Niggli values have been plotted in a diagram as a function of the parameter si (Fig. 3). Aluminium and alkali parameters increase steadily towards the silicic members and the femic parameters increase towards the contamination zone. The ratio mg has been plotted in a graph as a function of the ratio k (Fig. 4). Ratios for normal granite and quartz-diorite according to Niggli (1923) have also been plotted. The points representing these rocks are nearer to the ideal point of the quartz-diorite than to that of granite. There is a significant difference in the ratio k of the various rocks: it is seen to be higher in the heavily contaminated rocks. This point will be explained later.

There is a break in the curve of the c value of fig 3, as well as in the curve Ca of the cation percentage (Fig. 2). From the modal analyses, it appears that this is due to the high concentration of epidote (9.6% by volume) in sample 3. This is very probably occasioned by a local variation in the composition of the rock which has contaminated the granitic rocks. Nevertheless, the general trend of the phenomena is unaffected by this variation: there is a progressive decrease of mafic constituents and an increase in silica and soda constituents towards the interior of the massif. Mineralogically, this is expressed as a decrease in hornblende and biotite and an increase in plagioclase and quartz from the rim of the massif towards its interior.

The Niggli values of the grey "granitic" rock have been plotted for comparison in the same graph as those of the pink rock (figs. 3 and 4). It is rich in aluminium, silicon and alkalis.

Because of the presence of minerals such as hornblende and biotite, the norm is different from the modal composition. Also, in the contamination zone there may be a certain lack of equilibrium: some microxenoliths of hornblende mantled with biotite have stopped being replaced because the hornblende was isolated from further contact with the granitic liquid by a shell of biotite surrounding it. In these conditions, it is very difficult to work out the real mineralogical composition from the norm.

E. - ORIGIN OF THE "GRANITIC" ROCKS.

Logically, there are two explanations for the features observed. The first is: transformation or granitization "in situ" of amphibolites ^{and the second: emplacement of an intrusive magma} to form "granitic" rocks. In the southern portion of the massif, interaction between the "granitic" rocks and their amphibolitic wall-rocks is clearly

demonstrated. However, it must be kept in mind that, though the contaminated zone is fairly wide, the contact itself between the quartz-dioritic rocks and the basic wall-rocks is rather sharp when the dimensions of the whole "granitic" massif are considered. In the south, the wall-rocks described in chapter III can in places be seen to be broken and brecciated. The actual contact between the "granitic" rocks and the basic rocks in the Hlimbitwa valley is hidden by alluvia, but it must take place within 100 to 150 yards inaccessible to observation. The writer fails to see any proof that the "granitic" rocks could derive from the granitization of the amphibolites. Such an extensive granitization involves tremendous movements and migrations of matter plus the supply of the great quantity of energy required to complete the process. When one considers the scale and the extent of the phenomena which would be involved in granitization, it seems impossible that granitization should stop dead within 100 yards without the amphibolitic wall-rocks being otherwise modified than by local brecciation and partial recrystallization (without any supply of material from outer sources). Together with BOWEN (1948), the writer "denies... that it is proper to extrapolate to the whole body the metasomatic replacement relation that may be patent for part of its marginal facies".

The writer prefers to believe in the emplacement of an intrusive magma. In this case, the southernmost "granitic" rocks rich in calcic minerals must be considered to be the result of endomorphism, i.e. modification or contamination of the "granitic" rocks by the basic rocks.

The northern "granitic" massif has a trend more or less parallel with all the other belts. It must have been emplaced at some depth since the contaminated ^{at} zone is a few hundred yards wide; the wall-rocks must have been in a state of potential reactivity, attested by partial recrystallization of the amphibolites themselves (chapter III), otherwise a "normal" small contact aureole and not a thorough soaking of basic rocks by acid material over a few hundred yards would have been observed. This fits in with ESKOLA's (1932) definition of synkinematic massifs: concordant in structure and emplaced into highly mobile surroundings.

As for the dictyonitic structures, it should be recalled that this term designates the relationships between the coarser pink "granite" and the grey rock. The latter is the younger and corrodes the pink "granitic" rock.

The writer is of the opinion that two events must be distinguished here. The first is characterised by the emplacement at depth of the pink quartz-diorite magma. The whole massif must then have undergone uplift to higher levels of the crust where the solidified rock became brittle and underwent extensive brecciation and fragmentation into angular fragments. Into the interstitial spaces flowed the younger grey "granitic" rock. Why is the dictyonitic structure not observed in the contaminated rock? There is no obvious answer to this: the nature of the tectonic forces which induced the brecciation is not known. The northern margin of the "granitic" massif is hidden from view. It appears probable to the writer that this absence of brecciation in the contaminated rim could be explained by differences in mechanical behaviour between the contaminated and uncontaminated rocks. The contaminated zone is by no means free of fractures; faults involving a horizontal displacement of a few inches can best be seen with the help of dark patches or layers of mafic minerals which have been slightly offset by these faults. Though the latter may in places be very abundant, they lack the regular pattern of the fractures in the uncontaminated rock and scarcely reach 1 or 2 yards in length. The term brecciation cannot possibly be applied to these fractures. The replacement by grey "granitic" rock has taken place only where brecciation was extensively developed, i.e. in the uncontaminated "granitic" rocks. The brecciation could quite simply be due to the emplacement of the grey "granite" itself, perhaps by a process akin to "magmatic stopping".

It is well-known that in granitic massifs early fractures can be filled with a finer-grained later variety of the main rock. Is it the case here?

Firstly, the grey "granitic" rock cannot exactly be called a variety of the main, pink "granite", since it is richer in potash. Secondly, it must have been very mobile to form large patches sometimes more than 10 yards across in the pink "granitic" rock and to corrode it. This mobility would be quite unexpected if this rock were simply filling fractures in the pink "granitic" rock at a late stage of the latter's solidification.

In the writer's opinion, the emplacement of the grey "granitic" rock characterises a second event: it took place at deeper levels after renewed depression of the fractured pink "granitic" rock. The injection of more potassic "granitic" magma occurred along pre-existing fractures with partial solution of the pink quartz-diorite. Renewed depression and the

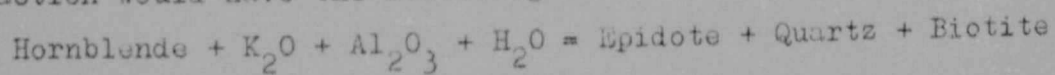
consequent elevation of temperature were sufficient to provide mobility to the magma of the grey "granitic" rocks, but insufficient to allow of the complete digestion of the pink "granitic" rock. This process must be envisaged as an oscillation in the uplift of the metamorphic complex rather than a complete palaeogenetic cycle.

F.- REACTION BETWEEN THE ACID MAGMA AND THE AMPHIBOLITIC WALL-ROCKS.

The most striking feature of the "granitic" rocks in the vicinity of their amphibolitic wall-rocks is their abundance in aggregates of hornblende and/or their alteration products: biotite associated with epidote, sphene, ore and apatite.

The writer regards the aggregates as microxenoliths, i.e. minute relics of basic rocks which have been soaked and impregnated with quartz-dioritic magma.

BOWEN (1928) has shown in his work on the reaction series that if hornblende comes into contact with molten magma already supersaturated with such a high member of the reaction series as amphibole, this mineral cannot enter the liquid stage (i.e. re-melt), but will be converted to the mineral with which the liquid is saturated at this moment. In this case, the latter was biotite and the hornblende was transformed into biotite. In this replacement excess lime from the hornblende is set free and crystallizes as epidote. Microscopic observation has shown that some quartz is also produced as a by-product of the reaction (symplektic association). There is no way of working out a chemical reaction, since there is no evidence that the reaction took place at constant volume but a qualitative reaction would have the following form:



A consequence of the above reaction is the inverse relation between the quantities of biotite and potash feldspar: in this reaction zone rocks rich in biotite do not contain much potash feldspar. The abundance of biotite decreases from the reaction zone towards the interior of the massif because the contamination by hornblende is higher in the rim of the massif. There is no possibility for potash feldspar to occur in large quantities in these rocks, since the potash has been fixed and nearly exhausted in the biotitisation of hornblende higher up in the reaction series, well above such low members as feldspars.

The dark aggregates are also relatively rich in sphene and apatite. These derive from the introduction of phosphorus and titanium from the acid magma and from their reaction with ore, always abundant in amphibolites.

The presence of clots of biotite-epidote-sphene-apatite at a few hundred yards from the contact, indicates that the contamination has been extensive and that these can be considered as relics or ghosts of these microxenoliths, with a nucleus of hornblende, which are to be found in the immediate vicinity of the contact and which have been completely altered towards the interior of the massif.

From the graphs in fig. 2 and 3, it is clear that there has been a progressive introduction of silica and alkalis (granitic constituents) from the intrusive magma into the reaction zone. At the same time, there is a progressive expulsion of mafic constituents towards the rim of the reaction zone. Farther towards the interior of the reaction zone, the basic rocks have been thoroughly soaked by the acid material and an abundant supply of thermic energy was available; the hornblende has been completely replaced and there has been a tendency towards the expulsion of excess mafic constituents. At the rim of the massif, where assimilation came to a stop, the thermal energy emanating from the main body of acid magma was soon exhausted in the presence of basic elements: these rocks are relatively rich in mafic constituents and the hornblende was only partially replaced.

It is seen from fig. 2 that there is a certain enrichment in the reaction zone in potash, relative to the main uncontaminated body. The writer assumes that this is due to the presence of basic material (hornblende) susceptible to reaction with potash to form biotite: potash in the contamination zone was soon exhausted by reaction with hornblende and tied up in biotite. This local deficit in potash of the liquid magma may have created a change in the chemical potentials of the various phases and some potash may have migrated towards the reaction zone to combine with "unreacted" hornblende. There is no doubt that such a migration would be greatly facilitated by the molten state of the magma at the moment.

To a certain extent, the controversial concept of front (WEGMANN 1935; REYNOLDS, 1943, 1944, etc. and others) could be applied here. However, the writer feels that the use of this ill-defined term might complicate the interpretation of a relatively simple phenomenon and confuse the reader as to the writer's position in the problem.

To summarise, the "granitic" massif has been emplaced at depth in contact with amphibolitic wall-rocks. Reaction has taken place between the two rock types with the effect that the amphibolite has been thoroughly soaked over a few hundred yards by the acid magma and that its hornblende was biotitised. To achieve this, supply of some extra potassium from the magma into the rim has been necessary. Also, migration of calcic elements towards the rim of the massif has occurred from the interior of the reaction zone. The fact that this reaction in the contamination zone is far from complete and that amphibolites situated farther to the south of the granitic massif have been unaffected by the latter, shows well enough that the supply of energy (mainly thermic) in intrusive granites (and thus endomorphism) is limited (FERMIER, 1956). To conclude, these phenomena are the result of thermodynamic disequilibrium between the "granitic" massif and its wall-rocks, at a level of the crust deep enough to allow of rather intense reaction between both rock types.

G.- THEORETICAL CONSIDERATIONS: RELATIONSHIPS BETWEEN QUARTZOFELDSPATHIC MINERALS.

Though this paragraph may seem out of place here, it appeared necessary to the writer first to give a full description of the massif and to clear up its origin before dealing with the important relationships between quartzofeldspathic minerals.

(a).- Corrosion of plagioclase by potash feldspar

In the rocks of the northern massif microcline frequently corrodes plagioclase. This phenomenon has been observed by various writers in acid and intermediate rocks: DEER (1935), OSTERWALD (1955), BELLIERE (1960) and others. Among these authors, BELLIERE has suggested an interesting solution: he has deduced from the study of the rocks of the Aiguilles Rouges massif in the Alps that this corrosion results from the features of the ternary system orthoclase-albite-silica at high water pressures. From the well-known phase diagram $\text{NaAlSi}_3\text{O}_8$ - KAlSi_3O_8 - H_2O after BOWEN and TUTTLE (1950), BELLIERE has inferred that-at high water pressure- the solvus must intersect the liquidus in a eutectic point. He then suggested that-in the ternary system Or-Ab- SiO_2 - the univariant line from this eutectic point on the join Or-Ab reaches a peritectic point somewhere in the triangular diagram. At this peritectic point, plagioclase would diminish in amount while microcline increases. This would explain the observed corrosion effects.

Elaborate as this suggestion is, the writer does not think that it is valid in the light of recent experimental work. In 1957, YODER, STEWART and SMITH have demonstrated that in the system $\text{NaAlSi}_3\text{O}_8\text{-KAlSi}_3\text{O}_8\text{-H}_2\text{O}$ the solvus peak rises at $0.014^\circ\text{C}/\text{bar}$. They also have determined the solvus at 5000 bars H_2O : at this pressure; solvus and liquidus have intersected in a eutectic point at 695° . So far, BELLIERE's assumption is right though he did not refer to this earlier work.

However, TUTTLE and BOWEN (1958) have published an $\text{Ab-Or-SiO}_2\text{-H}_2\text{O}$ diagram where they show the position of the cotectic minimum (quartz + alkali feldspar) at 830° at normal pressure. They have worked out the compositional change of this minimum up to 5000 bars: now^{here} in these diagrams is there room for a peritectic reaction. There is also a certain lack of precision in BELLIERE's reasoning since the average granite plagioclase is oligoclase rather than albite. This does not alter the writer's conclusions about the northern "granitic" massif, since the effect of calcium is to raise the plagioclase field in temperature and to move the cotectic minimum towards the orthoclase-silica join (GORDON SMITH, 1963) and does not alter the nature of this $\text{Ab-Or-SiO}_2\text{-H}_2\text{O}$ diagram.

Though somewhat lengthy, this discussion appeared necessary to the writer to rule out the possibility of this corrosion occurring in the normal course of crystallization in the system $\text{Or-Ab-SiO}_2\text{-H}_2\text{O}$.

At this stage, two hypotheses are left to explain this corrosion:

- (a) Potash metasomatism (introduction of material from outside sources)
- (b) Corrosion of plagioclase by late-magmatic potash-rich solutions.

Potash metasomatism is rather difficult to account for in these rocks. True, it has been shown that there was a redistribution of potassium (to a slight extent!) in the massif with enrichment in the reaction zone. However, this is only 'auto-metasomatism': migration of potassium occurred in the liquid phase towards the rim of the massif because of the formation of a gradient -by fixation of potassium in biotite- in the concentration of potassium in the liquid phase. Actually, this migration occurred at a rather high stage of the reaction series, when biotite was being formed from hornblende and, significantly, the rocks of the reaction zone are depleted in microcline. Also, this potassium 'auto-metasomatism' cannot account for this corrosion since the rocks of the uncontaminated area, which have not been affected by this migration, also show this phenomenon of corrosion.

There are no indications that a true potassium metasomatism has taken place in the "granitic" rocks, which-in fact-are poor in potassium. If potassium metasomatism had taken place, there is no reason why the wall-rocks should not have been affected to a certain extent, which they have not.

In the writer's opinion, hypothesis (b) is closer to reality. If natural systems were exactly within the $\text{Ab-Or-SiO}_2\text{-H}_2\text{O}$ system, the lowest temperature at which a silicate liquid could exist would be 660° . (BOWEN and TUTTLE, 1958). But, according to BOWEN and TUTTLE, in natural system there would probably remain a silicate liquid below this temperature. The composition of this residual liquid would be in the $\text{Na}_2\text{O-K}_2\text{O-SiO}_2\text{-H}_2\text{O}$ system. ROY and TUTTLE (1956) have shown that there is complete solubility in the system $\text{K}_2\text{O-SiO}_2\text{-H}_2\text{O}$ between anhydrous silicates and water; TUTTLE and FRIEDMAN (1948) have found the same relationship for $\text{Na}_2\text{O-SiO}_2\text{-H}_2\text{O}$. GORDON SMITH (1963) has pointed out that in practice the difficulty is enormous, the system to be considered being quartz $\text{Ab-Or-H}_2\text{O-Na}_2\text{O-K}_2\text{O-MgO-CaO-B}_2\text{O}_3\text{-P}_2\text{O}_5\text{-HF-HCl-SO}_3\text{-H}_2\text{S}$ etc. with P and T as additional variables.

Suffice it for these purposes to conclude that the components, of alkali silicates may exist in excess in late-magmatic fluids. As early as 1928, BOWEN demonstrated that potash increases relatively to soda in late differentiates. In these rocks, where the plagioclase is oligoclase or andesine, the plagioclase field in the system plagioclase- Or-SiO_2 will be wide and, as plagioclase is much in excess, this mineral will be the first to crystallize. The comminution of the plagioclase has been described and it was pointed out that the microcline was not affected by this cataclasis (except for a few unimportant cracks). The crystallization of the microcline has thus taken place after the main period of cataclasis. The writer suggests that the potassium silicate was taken in solution in residual water (probably under complex physical conditions due to the synkinematic nature of the massif). Later on, this late-magmatic solution would replace soda by potash under the law of mass action (O'NEILL, 1948). This may be rendered qualitatively by the following reaction (purely hypothetical) $2\text{NaAlSi}_3\text{O}_8 + \text{K}_2\text{O} = 2\text{KAlSi}_3\text{O}_8 + \text{Na}_2\text{O}$

The soda may be eliminated as sodium carbonate solutions in thermal waters (ESKOLA, 1956).

This replacement is particularly conspicuous in granulated plagioclases or along cracks of this mineral where deformed crystal lattices have permitted easier corrosion.

Another problem crops up here: the origin of the myrmekites. The name myrmekite was given by SEDERHOLM in 1899 to wart-like associations of plagioclase and vermicular quartz. Various conflicting explanations have been proposed for the origin of myrmekite: magmatic corrosion (FOUQUE and MICHEL-LEVY, 1879), superficial alteration (ROSENBUSCH, 1887), calcosodic solutions transforming orthoclase (BECKE, 1908), secondary transformation of plagioclase (SEDERHOLM, 1916) etc. In 1948, DRESCHER-KADEN demonstrated the existence of two types of myrmekite: myrmekite I, formed from plagioclase by orthoclase-bearing solutions, and myrmekite II, formed by siliceous hydrothermal metasomatism along the separation surfaces of orthoclase and plagioclase. SPENCER (1945) and TUTTLE (1955) believe that the constituents of myrmekites were in solid solution in potash feldspar at high temperature. This welter of explanations is rather inconclusive. SPENCER's and TUTTLE's hypotheses in general seem rather plausible to the writer, but obviously cannot apply to this type of rock, in which the crystallization of microcline is the result of late-magmatic reactions at relatively low temperature. In 1955, ROQUES worked out the transformation of plagioclase to myrmekite for the first time in a quantitative way. He demonstrated that for the transformation to take place only silica is needed, while alumina, lime and soda are being released. Also, myrmekites can form from potash feldspar in the vicinity of plagioclase with introduction of silica, soda replacing potash and alumina being leached out.

In the rocks of the northern massif, most myrmekites are older than the potash feldspar and younger than the plagioclase. They can be ascribed to type I of DRESCHER-KADEN (from a descriptive point of view). These growths are partly dissolved by the potash feldspar; the albite in the myrmekites is dissolved by the potash feldspar but droplets of quartz are usually not assimilated and remain in the potash feldspar isolated from the rest of the intergrowths. This type of corrosion has been observed by BUGGE (1943). Also, a few myrmekitic warts growing from the plagioclase into the microcline have been noticed in this "granite", though they are not as abundant as the first type of myrmekite. In the light of ROQUES' paper, both phenomena can be explained by the action of silica-containing residual liquids on plagioclase (or on microcline in the last case.)

Thus, myrmekitisation has mainly occurred before the crystallization of microcline and also after, in the few occurrences of warts growing into the microcline. Actually, myrmekitisation is responsible for the corrosion of plagioclase.

This brings up a third problem: the origin of the perthitic texture of the microcline. These perthites are of the string type. They are often concentrated on the rim of the microcline crystals in the vicinity of the plagioclase. Whenever myrmekite is corroded by microcline, a cluster of albitic strings occurs in the potash feldspar at the contact or in the vicinity of the intergrowth. Exsolution of sodium feldspar in solid solution in potassium feldspar at higher temperature cannot explain these perthites (this microcline has been formed at low temperature) and would be contrary to its occurrence in the vicinity of myrmekites. Hence, it must be admitted that some albite of the myrmekites has been taken into solid solution in the microcline during corrosion and has been exsolved in the areas of higher concentration-adjacent to the myrmekites- as string perthites. Relics of plagioclase in potash feldspar are often devoid of a myrmekitic rim: the potash feldspar has completely corroded the myrmekite. In the rocks of the northern massif, the plagioclase has been partly albitised by myrmekitisation; when microcline formed, it corroded this albite.

The exsolution of perthite is also connected to a lesser degree with parts of the microcline crystals which have been subjected to stresses. Though these crystals have undergone nothing like the granulation that affected the plagioclase, some crystals have been fractured or their edges have been slightly strained. These parts of the crystals show a high development of albitic strings. As suggested by GATES (1953) and MICHOT (1938), the strained lattice of microcline seems to have difficulties in keeping the albitic component in solid solution and exsolves it.

A few occurrences of potash feldspar in plagioclase have been observed: they are intergrowths and result from the exsolution at lower temperature of some potash feldspar which was in solid solution in plagioclase feldspar at higher temperature (antiperthite).

To conclude, at some stage of the crystallization, molten silicates have been taken into solution with water in late magmatic fluids. This liquid has reacted with plagioclases: silica has been transferred to the

reaction zone, corroding plagioclase and generating myrmekites. In turn, microcline has crystallized from this liquid, or formed by the reaction of potash with the albite of the myrmekites, and was on its edge-unable to assimilate completely the excess albite which was exsolved in perthite form. Since a little microcline has been albitized (myrmekite warts), siliceous solutions were still slightly active after the formation of microcline. In the writer's opinion, all these textures are the result of low temperature reactions. Though this is highly speculative, the granulation of the plagioclase seems to have played a very important role in these replacements by creating stresses in the plagioclase lattice and increasing its reactivity.

(b).- Relationships between quartz and plagioclase.

Complex relationships have been observed between quartz and plagioclase: quartz may occur in large rounded relics in plagioclase (without any relationship with myrmekite!), but these same crystals of plagioclase may also be corroded by other quartz grains.

DRESCHER-KADEN (1948) has explained these textures by complex metasomatism actions. BELLIERE (1958) has found the same texture in gneisses where no metasomatism has taken place and explained them by the local effect of dislocations in crystals. The writer supports the latter hypothesis, with a few additional remarks. BELLIERE called these associations "mutual corrosion textures". This mutual corrosion is different from the corrosion of plagioclase by microcline which is not reciprocal; there is no corrosion of microcline by plagioclase. The importance of dislocations and imperfections in crystals has been emphasised by DEKEYSER and AMELINCK (1955) and by TURNER and VERHOOGEN (1960). These dislocations are promoted by deformation and they may provide channelways for migrating material (RAMBERG, 1952) and facilitate replacement processes; for instance, the solubility of quartz has been shown to increase with the degree of crushing of this material (JACKSON and TRUOG, 1939). In the description of the northern "granitic" rocks, it has been shown that these rocks have undergone cataclasis to a certain extent. This deformation must have generated many crystal defects in plagioclase, as well as in quartz, and this led to mutual replacement of these minerals. Also important is the existence of differential tensions: locally, pressures may reach a degree where the plagioclase or the quartz is no longer in equilibrium with the liquid phase and dissolves again in it. Accordingly, quartz is seen to

replace mainly the granulated plagioclase and has little effect on larger ungranulated plagioclase.

This mutual corrosion may also occur in aggregates of quartz between quartz grains and is best seen by the use of the gypsum auxiliary plate.

(c).- Granulation of the Plagioclase.

Mechanical stresses have been shown to granulate plagioclase crystals and to break them down into fine-grained aggregates made of delicately imbricated and strain-free tiny plagioclase crystals. The writer attributes these features to recrystallization. The fact that recrystallization yields fine-grained aggregates rather than large crystals is not unusual and has been noted by TURNER and VERHOOGEN (1960) as rather common.

(d).- Conclusions.

The relationships between quartz and feldspars have been shown to be complex. They are the result of a combination of factors: deformation and reaction of late magmatic solutions with early-formed minerals.

Deformation has been important in facilitating replacement processes by late-magmatic solutions; to quote GLANGEAUD (1947): 'If the crystalline, vitreous and liquid states are very well-known to physicists and chemists, the same cannot be said of dynamomorphic states. These are known to tectonicians and petrologists as cataclastic textures'.

III.- SATELLITIC ACID DYKES: PEGMATITES, APLITES AND TRONDHJEMITES.

A.- Pegmatites and aplites.

These rocks are particularly abundant in the rim of the "granitic" massif. Photos 44 and 45, Plate XXIII, will give an idea of their complexity. Aplites are seen to cut pegmatites (Photo 45, Plate XXIII) and occur in fissures or even in faults offsetting the pegmatite veins (same Photo).

Thin quartz veins are also numerous and may be intersected by both pegmatites and the aplites or in turn intersect these. Photo 46, Plate XXIV shows some quartz veins which have been offset by the emplacement of small intrusive and dilative aplitic veins with chilled borders.

The pegmatites are never more than a few yards wide and along strike peter out after a short distance.

The aplites are usually much more continuous and may occur in composite dykes 2 to 3 yards wide (Photo 47, Plate XXIV). One of these is composed of as many as three different-looking types of rock: a fine-grained aplite (grain-size less than 1 mm.), an aplite characterized by

parallel alignment of thin biotite flakes; and a coarser-grained aplite (up to 2 mm.). Quite a few aplite dykes follow the same trend as some of the basic dykes (Photo 47, Plate XXIV and photo 48, Plate XXV); they are seen to be cut by the basic dykes, which must therefore have been emplaced at a later stage. Deformation of the "granitic" host-rock has sometimes folded or offset some of the aplite veins, which then pass laterally into swarms of folded inclusions, as in photo 49, Plate XXV.

Under the microscope, the aplites are composed of plagioclase, microcline and quartz. The composition of the plagioclases ranges from andesine $40\% \text{ Ar}_{40}$ to oligoclase $15\% \text{ An}_{15}$. They are twinned according to the albite law and their maximum size is 2.0 mm. They are more or less corroded by microcline which is perthitic and may reach 2.0 mm. across. The quartz is 2.0 mm. wide and very corrosive. It is often intergrown with plagioclase. Accessories are chloritized biotite, epidote and sphene. Modal analyses are given in table 26.

TABLE 26

	I	II	III
Plagioclase	57.7	22.3	28.2
Microcline	4.2	9.0	28.8
Quartz	35.1	63.2	42.4
Chloritized biotite	1.8	3.0	0.4
Sphene	0.5	2.5	-
Epidote	0.7	-	0.2
	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>

There is evidently a rather large variation from sample to sample.

Under the microscope the pegmatites show the same characteristics as the aplites, but their grain-size is up to 10 cm.

B.- Trondhjemites.

All over the rim of the massif, dykes of light coloured rock cut across the "granitic" rocks. They are 8 to 20 ft. thick and cut the pegmatites and the aplites. However, they may in turn be transected by networks of thin aplite veins. Thin basic dykes may also cut these dykes (Photo 51, Plate XXVI). However, some of the trondhjemite dykes which have been emplaced against thick porphyroblastic basic dykes have shattered the basic rock in the contact zone. Veinlets of acid material

have been injected into the basic rock. Acid dykes are thus younger than some of the basic dykes.

Modal analyses of these rocks are given in table VI-27.

They are seen to be widely divergent. These rocks all have in common a great abundance of silic minerals (from 80 to 90%) and a very low colour index. They are best described by the term TRONDHJEMITE.

TABLE VI-27

	Plag.	Mi.	Ho.	Bi.	Qz.	Ep.	Sp.	Ore
<u>1</u>	77.5	4.8	-	4.5	12.2	0.8	0.2	-/100.0
<u>2</u>	49.0	5.4	0.6	2.4	38.8	2.1	0.7	1.0/100.0
<u>3</u>	57.2	7.0	-	5.0	22.2	7.6	-	1.0/100.0

Under the microscope, they are seen to consist of porphyroblastic plagioclase (5 mm.) occurring in a groundmass of plagioclase (0.1 to 0.5 mm), microcline (1 mm.) and quartz (0.01 to 0.5 mm.), with some biotite, sphene, epidote and hornblende.

The plagioclases have compositions ranging from andesine ^{An₄₀₋₃₀} ~~30 to 40~~ in the porphyroblasts which are positively zoned and twinned according to the albite-Carlsbad law. The plagioclases in the groundmass have compositions ranging from andesine ~~33%~~ ^{An₃₃} to oligoclase ~~28%~~ ^{An₂₈}. The latter are corroded by interstitial veins or grains of microcline. Biotite occurs in schlieren or in aggregates and is then associated with epidote, sphene and ore. It is strongly chloritized and altered to sphene. Hornblende is scarce and is slightly altered to biotite and epidote. Quartz occurs in aggregates of several crystals.

C.- Conclusions.

Pegmatites and aplites are abundant in the rim of the massif and most of these veins have been emplaced in fractures, i.e. when the "granitic" massif was more or less solidified. This occurrence is due to the fact that, when the magma solidified, fluid phases tended to escape from the massif and formed pegmatitic and, later on, aplitic veins in the fractures of the cooler rim of the massif. Trondhjemite veins are more difficult to account for. The writer has noticed a striking similarity between them and the contaminated "granitic" rocks of the rim from a qualitative point of view; they too have aggregates of biotite with epidote, sphene and ore which are identical with the relics of microxenoliths found in the contaminated ^{at} rocks; they also show a few crystals of hornblende being

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