The West Humboldt layered intrusion is a two-layer sheet exposed over a half square mile in the West Humboldt Range, Nevada. The body is composed of 235+ feet of hornblende picrite overlain by at least 100 feet of anorthositic hornblende gabbro. The strong bistratal segregation of early crystallized minerals in this body is quite remarkable in view of the absence of cryptic layering (as defined by Hess, 1960), grain size sorting, or mineral rhythms within each layer. A second striking feature of this intrusion is the pervasive planar fabric defined by tabular plagioclase. The attitude of this foliation is similar in both layers and lies at high angles to the interface of the two layers and the base of the sheet.

The layering and fabric of this body are clearly unlike those of other layered gabbros reported in the literature and in this symposium. The object of this paper is to suggest a possible origin of the layered body which accounts for these unusual features. Detailed study of the intrusion is yet to be completed, but the problems mentioned above are sufficiently well established and of such an unusual nature that presentation at this symposium seems warranted.

**GEOLeOGIC SETTING**

The West Humboldt layered intrusion is part of the Humboldt gabbroic complex (Speed, 1962), a large mass of hornblende gabbro with minor picrite, anorthosite, dolerite, keratophyre, and gabbroic pegmatite. The complex crops out in the adjacent northerly-trending West Humboldt, Stillwater, and Clan Alpine ranges in northwestern Nevada and has a known extent of at least 35 miles in maximum dimension. The gabbroic rocks were studied chiefly in the West Humboldt Range (Fig. 1) where they form a quasi-tabular body which dips east off the east flank of the range under the Quaternary deposits of the adjacent basin. Stratigraphic evidence indicates that the age of the complex is between Lower Jurassic and Upper Tertiary. Emplacement of the complex was at a shallow depth, probably less than 2500 feet, and was apparently synchronous with regional deformation of the intruded Mesozoic sediments.

Hornblende picrite and strongly foliate hornblende leucogabbro which compose the West Humboldt layered body crop out chiefly along the western periphery of the Humboldt gabbroic complex in the West Humboldt Range. These units were earliest in the sequence of rock types forming the complex. Some of the relatively large bodies of these two facies are shown in Fig. 1. The consistent areal association of picrite and foliate leucogabbro indicates that these facies are cogenetic. Structural evidence suggests that all of these bodies are contemporaneous and may once have been contiguous. Deformation, widespread deuteric alteration, and poor exposures preclude more definite correlation of these bodies.

**WEST HUMBOLDT LAYERED SHEET**

**Structure.** The West Humboldt layered intrusion, shown in Fig. 2, is tabular and consists simply of
235+ feet of hornblende picrite overlain by at least 100 feet of anorthositic hornblende gabbro. The contact of the two layers is not exposed, and an approximate contact was mapped by tracing the sharp mineralogical change in the surficial debris. Field examination in nearly vertical sections through the body indicated that the contact is either sharp or gradational through no more than 15 feet.

**FIG. 1.** Generalized geologic map of West Humboldt Range, Nevada, showing distribution of gabbroic rocks and location of West Humboldt layered intrusion.
The roof of the intrusion has been completely eroded, and the maximum thickness of the leucogabbro above exposed picrite is about 100 feet. This layer may thicken in the eastern part of the body if the picrite-leucogabbro contact maintains a constant attitude east of its easternmost exposure. The picrite is estimated to be around 235 feet thick in the western part of the body. The thickness of other parts of the picrite is poorly known because of the lack of vertical exposures through this layer and uncertainty in the attitude of the base of the sheet. The picrite, however, appears to thicken in the eastern part of the body.

The base of the picrite lies partly on deformed
marble and hornfels and partly on younger hornblende gabbro. The concordance between the igneous sheet and the marble suggests that the body is a sill. Marble, however, is also widespread in thrust zones in the West Humboldt Range; therefore, the structural setting of the intrusion is uncertain. Attitudes of the marble segments form an anticlinal pattern, the axis of which roughly parallels axes of folds in the metasedimentary terrane which trend about N.10°E. and plunge shallowly. Most of these folds are overturned to the west. The degree of folding of the layered intrusion, however, cannot be determined as most of the western limb of the body is faulted. The internal fabric of the layered sheet suggests that the intrusion was deformed prior to final consolidation.

**Hornblende picrite.** Hornblende picrite forms a rather homogeneous petrographic unit in which internal layering is absent. Modal variation in the picrite consists chiefly of a gradual increase in color index vertically in the layer. Modal and chemical analyses of specimens taken near the bottom, middle, and top of the picrite are reported in Table 1. Analyses 1 and 3 represent the approximate limits of mineralogical and chemical variation in the picrite. Textures in both the picrite and the leucogabbro clearly indicate a sequence of crystallization of mineral assemblages. The early crystallizing assemblage in both facies is believed to be composed of accumulative minerals. This is indicated by the strong segregation of these minerals into two layers on the basis of their densities. The later crystallizing assemblages formed by reaction of the cumulus minerals with the intercumulus liquid and by in situ precipitation of this liquid. Terminology is taken from Wager et al. (1960).

The early crystallizing assemblage in the picrite is composed of olivine, labradorite, and clinopyroxene. That crystallization of olivine started first is indicated by the inclusion of small olivine grains in clinopyroxene and labradorite. Olivine has a wide range of grain size and idiomorphism. Maximum dimension of olivine grains in thin section ranges from 0.5 to 5.0 mm. This range of grain intercepts is believed to indicate variation in actual size of olivine grains. In some sections olivine grains with small intercepts are clustered in a manner which indicates that all the grains in the cluster could not have been considerably larger at levels above or below the plane of the thin section. Furthermore, euhedral olivine grains whose intercepts differ by an order of magnitude are in near-contact; it is difficult to envision how the two grains

### Table 1. Chemical and Modal Analyses of Rocks from the West Humboldt Layered Intrusion

<table>
<thead>
<tr>
<th>Chemical Analyses</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>SiO₂</td>
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<tr>
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<td>6.10</td>
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</tr>
<tr>
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<td>0.14</td>
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<tr>
<td>MgO</td>
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<td>23.40</td>
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<td>CaO</td>
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<td>3.63</td>
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<tr>
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<tr>
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<td>3.02</td>
<td>5.12</td>
<td>1.86</td>
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<td>H₂O⁻</td>
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<tr>
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<tr>
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<td>0.05</td>
<td>0.05</td>
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</tr>
<tr>
<td>F</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td>99.38</td>
<td>99.91</td>
<td>99.52</td>
<td>99.72</td>
</tr>
<tr>
<td>Norms</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Or</td>
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<td>2.26</td>
<td>1.93</td>
<td>3.74</td>
</tr>
<tr>
<td>Ab</td>
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<td>13.15</td>
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<td>0.33</td>
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<tr>
<td>Il</td>
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<td>1.02</td>
<td>0.96</td>
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<td>Mt</td>
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<td>5.10</td>
<td>1.92</td>
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<td>MgO %</td>
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<td>90</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td>MgO + FeO</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An %</td>
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<td>59</td>
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<td>53</td>
</tr>
<tr>
<td>Modes</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Olivine</td>
<td>25.4</td>
<td>34.0</td>
<td>38.5</td>
<td></td>
</tr>
<tr>
<td>Fe% (85–87)</td>
<td>3.5</td>
<td>2.5</td>
<td>3.3</td>
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<tr>
<td>Bronzite</td>
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<tr>
<td>En% (80–82)</td>
<td>11.4</td>
<td>10.5</td>
<td>8.5</td>
<td>18.0</td>
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<tr>
<td>Clinopyroxene</td>
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<td>28.1</td>
<td>21.6</td>
<td>73.7</td>
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<tr>
<td>Kaersutite</td>
<td>55–60</td>
<td>55–60</td>
<td>55–60</td>
<td>55–60</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>2.3</td>
<td>2.3</td>
<td>3.8</td>
<td>0.3</td>
</tr>
<tr>
<td>An% (55–60)</td>
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<td>2.0</td>
<td>3.2</td>
<td></td>
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<tr>
<td>Magnetite</td>
<td>14.2</td>
<td>6.1</td>
<td>6.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Titanobiotite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorite¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphene</td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

¹ Deuteric chlorite replacing both plagioclase and olivine.
1—Hornblende picrite—10 feet above base.
2—Hornblende picrite—170 feet below leucogabbro contact.
3—Hornblende picrite—15 feet below leucogabbro contact.
4—Hornblende leucogabbro—30 feet above picrite contact.

Specimen locations shown on Fig. 2.

Analyst: Y. Chiba.
could have similar actual dimensions. Perfectly
euhedral and highly irregular anhedral olivines are
both abundant. Optical measurements indicate a
composition range of Fo$_{85-92}$, but it is probable that
the spread is due to errors in measurement as the ma-
ajority of measurements indicates Fo$_{87}$. Zoning is ab-
sent in olivine. Layering with respect to composition,
size, or shape of olivine was not observed.

Labradorite in the picrite occurs chiefly in tablets
which are as long as 12 mm. The tablets contain as
many as 50 oscillatory zones. The most calcic zone is
An$_{85}$, but most zone compositions are in the range
An$_{82-85}$. Some labradorite tablets have a thin rim of
normally zoned plagioclase, the periphery of which
is as sodic as An$_{85}$. The rims probably crystallized
after accumulation. Labradorite forms irregular
monomineralic clusters at a few places. Long dimen-
sions of the clusters generally parallel the planar
feldspar fabric.

Clinopyroxene occurs both as discrete subhedral
and euhedral grains and in monomineralic glomo-
roporphyritic clusters in which component grains are
highly intergrown. Many clinopyroxenes have oscill-
atory zoning, but others are apparently of uniform
composition. Optical variations in zoning are chiefly
in optic angle (52-54° and 58-60°) whereas differ-
ences in refractive index ($\beta = 1.682 - 1.686$) and
$\sqrt{g}c$ (40-42°) between zones are small. Unzoned
clinopyroxene optic angles are 53-57°. Accordingly,
clinopyroxene compositions fall in the interval
Ca$_{42}$-30Mg$_{39-48}$Fe$_{7-10}$. Maximum grain intercepts of
clinopyroxene clusters and single grains are 4.0 mm.

Two intercumulus assemblages occur in the picrite.
The earlier consists of orthopyroxene and sodic rims
on cumulus labradorite. The later assemblage is com-
posed of kaersutite, titanobiotite, and magnetite. Ortho-
pyroxene is virtually restricted to sinuous
poikilitic nets which envelop and replace olivine
grains. In other picrite bodies in the West Humboldt
Range, however, orthopyroxene occurs in large (12
mm) poikilitic nets enclosing clinopyroxene and
plagioclase as well as olivine. This texture indicates
that orthopyroxene was a product both of reaction
of olivine with the intercumulus liquid and continued
direct precipitation from the liquid. Orthopyroxene
compositions range from En$_{80}$ to En$_{87}$.

The foregoing minerals are enveloped by large
poikilitic nets of kaersutite (4.9% TiO$_2$) and titano-
biotite. Amoeboid grains of magnetite occur only in
kaersutite and titanobiotite and are apparently con-
temporaneous with the latter minerals. These three
minerals compose the late assemblage which crystal-
lized from the intercumulus liquid. Clinopyroxene
and, to a less extent, orthopyroxene are highly re-
placed by kaersutite and titanobiotite, but replace-
ment of olivine and plagioclase by these minerals did
not occur.

Most of the rocks of the layered sheet were
strongly hydrated in the deuteric stage. Much of the
olivine and orthopyroxene was altered to talc, tremo-
lite, bowlingite, magnetite, and serpentine minerals.
Labradorite was partly replaced by combinations of
prehnite, chlorite, pumpellyite, grossular, analcite,
albite and white mica. Kaersutite was partly altered
to actinolite, chlorite and sphene. Reciprocal move-
ment of Ca and Mg is indicated by the replacement
of labradorite by chlorite and olivine by tremolite at
places where the two primary minerals were in con-
 tact. The original grain contacts are obscured by the
alteration, and the amount of chlorite representing
former olivine or plagioclase cannot be ascertained.
This chlorite is reported separately in the modes in
Table 1, but textures indicate that the chlorite chiefly
replaces plagioclase.

Hornblende leucogabbro. Modal variations in horn-
blende leucogabbro are largely in the relative amount
of plagioclase (70-95%) and late amphibole. Clin-
opyroxene rarely forms more than 5% of the leuco-
gabbro, and in many specimens, it is absent. System-
atic vertical or lateral trends in these varia-
tions in the leucogabbro were not found. Chemical
and modal analyses of a representative leucogabbro
are given in Table 1.

Labradorite and clinopyroxene form the early
crystallizing assemblage in the hornblende leuco-
gabbro facies. Relics or alteration products of olivine
or orthopyroxene were not observed in the leuco-
gabbro. Plagioclase tablets are generally larger and
the peripheral jackets are thicker in the leucogabbro
than the picrite. The contrast in zoning and composi-
tion of the jackets and the core suggests that the two
crystallized under considerably different conditions.
The cores almost certainly are part of the cumulus
assemblage; it is suggested, therefore, that the rims
grew from the intercumulus liquid. The average
composition of the cumulus parts of the leucogabbro
plagioclase appears to be uniform throughout the
layer and to differ little from that of the picrite plagi-
oclase. Clinopyroxene in the leucogabbro occurs both
in equant and highly elongate subhedral. Clinopyrox-
ene compositional limits in the leucogabbro are sim-
ilar to those in the picrite.

The intercumulus assemblage in the leucogabbro
is composed chiefly of kaersutite with a little magne-
tite and apatite. Titanobiotite does not occur in the
leucogabbro. Modal apatite appears to be far more abundant in the leucogabbro than the picrite, though normative apatite is similar in the two facies. The abundance of the intercumulus minerals in the leucogabbro is between 1.5 and 2 times that in the picrite.

Fabric. One of the most striking features of the West Humboldt layered sheet is the strong planar fabric formed by the alignment of plagioclase tablets in both layers of the body (Fig. 3). Foliation symbols in Fig. 2 indicate the similarity of attitude of the fabric in the two layers and the fact that the planar fabric is at a high angle to the interface of the two layers and the projected base of the sheet. Figure 4, an equal area plot of poles to the feldspar fabric, shows that the preferred orientation is generally similar throughout the body.

Bent twins, shattered grains, and other evidence of protoclasis are absent. Discordant plagioclase tablets contact one another without deformation. Clearly, the fabric must have been formed in a benign manner. Sawed slabs of leucogabbro were examined for lineation, and it is clear that prominent lineation is absent. It is possible, however, that if a large number of careful measurements were made, a slight lineation might be discovered.

Vertical variations. Vertical variations in the West Humboldt layered intrusion are summarized as follows:

A. Mineral Layering
1. Restriction of olivine, orthopyroxene, and titanobiotite to the picrite.
2. Greater content of clinopyroxene in the picrite than the leucogabbro.
3. Greater amount of plagioclase, kaersutite, and apatite in the leucogabbro than the picrite.
4. Ratio of olivine and clinopyroxene to plagioclase increasing stratigraphically upward in the picrite.

B. Textural Variations.
1. Average plagioclase grain size larger in the leucogabbro than the picrite.
2. Clinopyroxene single grains and clusters a little larger in the picrite than the leucogabbro; clinopyroxene in the leucogabbro more elongate.

The mineral variations indicate the strong separation of the cumulus minerals into two layers on the basis of density. The greater content of the intercumulus minerals in the leucogabbro than the picrite indicates the higher intercumulus porosity (lower crystal/liquid ratio) in the upper layer prior to crystallization of the intercumulus liquid.

Cryptic layering of the cumulus phases is apparently absent within the intrusion. Olivine composition is constant throughout the picrite, and the range of 2V and β of clinopyroxene at different levels in the sheet is similar. The consistent values of normative MgO/MgO+FeO on the analyzed picrites in Table 1 supports the modal evidence that the mafic minerals do not become more iron-rich at higher stratigraphic levels. Magnetite is a product of deuteric alteration of olivine in the picrite. Consequently, normative magnetite content of the picrites
is higher than that of modal magnetite, and the ratio of normative MgO/MgO+FeO is higher than it was prior to alteration. Bulk modal plagioclase composition, though difficult to estimate because of complex zoning, appears not to differ at succeeding stratigraphic levels in what is taken to the cumulus part of the mineral. This is supported by the similar values for normative plagioclase in the analyzed picrites of Table I. The larger average volume of the intercumulus plagioclase rims in the leucogabbro, however, makes the normative plagioclase in the leucogabbro more albitic than that of the picrite.

Glomeroporphyritic clots of clinopyroxene and plagioclase are the only monomineralic aggregates in the intrusion. The clinopyroxene clots are generally equant; the plagioclase clots are both equant and lensoid, the latter type lying parallel to the planar fabric of the rock. Rhythmic mineral layering is absent. Sorting within each of the facies as a function of grain size or shape was not observed.

PETROLOGY OF THE LAYERED INTRUSION

The rocks along the base of the sheet are so altered that the existence of a chilled zone could not be determined. Consequently, the composition of the parent magma or the degree of crystallinity of the magma on emplacement are unknown. In a qualitative way, however, the two facies appear to be complementary fractions of an olivine gabbro. This suggests that the two layers are differentiates of a single injection of basaltic magma. The continuity of the feldspar fabric between the two layers strongly supports the view that the layers were not separate injections. The fact that rocks throughout the complex have a late-crystallizing alkaline assemblage indicates an alkali magma type.

Differentiation of the magma consisted of two concomitant processes, vertical segregation of the early formed minerals into upper feldspathic and basal mafic layers and strong changes in the composition of the liquid phase with progressive crystallization. Following accumulation of olivine, plagioclase and clinopyroxene, succeeding events were: 1) crystallization of orthopyroxene and sodic plagioclase rims and development of the planar fabric, and 2) crystallization of kaersutite, titanobiotite, magnetite and apatite. The contemporaneity of the feldspar rims with orthopyroxene rather than the other intercumulus minerals is suggested by the coexistence of kaersutite with magmatic analcite in other rocks of the complex. The contrast of orthopyroxene textures in the foliate picrite of the layered intrusion to those in nonfoliate picrite to the south

in the West Humboldt Range suggests that crystallization of large continuous orthopyroxene webs in the former picrite may have been mechanically prevented by concomitant reorientation of platy plagioclase.

The second group of intercumulus minerals filled the remaining pore space as well as partly replacing the earlier pyroxenes. The composition of this late crystallizing assemblage must be close to the non-volatile composition of the intercumulus liquid near its final consolidation. The late magma contained only 31–40% SiO₂ but was enriched in iron (15–30% total iron as FeO), soda, and probably in volatiles. This liquid was probably highly fluid. The liquid line of descent shows a remarkable retention of iron in the liquid phase. An account of the differentiation of the entire complex will be presented elsewhere.

ORIGIN OF THE LAYERING

The two-layer distribution of early crystallizing minerals strongly indicates the influence of gravity during differentiation. The absence of rhythms or sorting in either layer, however, indicates that deposition of the cumulates in this body did not involve the current mechanisms that were apparently operative in other layered gabbros (Wager and Deer, 1939; Hess, 1960). The original thickness of this body is unknown, but the known or inferred thickness of other parts of the gabbroic complex in the West Humboldt Range suggest that it did not greatly exceed 500 feet. The rate of cooling, therefore, was probably similar along all surfaces of the magma chamber, and the change of melting point of crystallizing phases with depth in the chamber was probably not a significant factor in their distribution.

The uniformity of composition of the cumulus minerals, each of which forms a solid solution series, indicates that they crystallized from magma of constant composition with respect to the ratios of high temperature to low temperature components of the series. Fresh magma, therefore, must have continually been brought to the cooling surfaces where crystallization occurred, and magma movement must be invoked to account for the absence of cryptic layering. Yet, convective overturn or other flow mechanisms cannot be called upon to circulate fresh magma considering the lack of rhythms or sorting of the cumulates which would have been deposited concomitantly with the rise of fresh magma. Another feature to be accounted for is the upward increase in color index in the picrite.

The layering can be explained in part by the suggestion that the cumulus minerals had largely crystal-
lized before the magma was emplaced. Olivine, clino-
pyroxene, and plagioclase could have crystallized
with little change of composition during rise of the
magma through the conduit if the upward flow was
turbulent enough to bring fresh magma to the walls
and sweep the crystals away from the peripheral
parts of the conduit. The complex zoning of the
feldspar and some clinopyroxene suggests rapid
 crystallization under varying conditions. The re-
lative movement of crystals and crystal aggregates of
olivine, clinopyroxene, and plagioclase during sedi-
mentation that followed magma emplacement may
account for the layering and petrographic variations.
The mafic phases would clearly have settled through
the liquid, and it is suggested that plagioclase may
have had a slight tendency to rise. The ratio of
plagioclase to interstitial amphibole is lowest at the
base of tabular bodies of feldspathic gabbro at other
places in the complex. This suggests that plagioclase
was less dense than the late liquid.

The settling of olivine and clinopyroxene simul-
taneously throughout the magma chamber probably
involved increasing amounts of aggregation of the
sinking grains with time. The sedimentation process
might be viewed as the compaction of a cloud of
crystal aggregates rather than as the settling of dis-
crete particles. Sorting during deposition of this
type should have been poor. Much plagioclase was
probably dragged down by the descending mafics.
Feldspar crystals near the chamber roof had fewer
waves of mafic grains and aggregates sinking past
than did feldspars at lower levels, and the opportu-
nities for feldspar to have been swept down were less
at higher levels in the chamber. On the other hand,
feldspar at the base of the magma chamber was prob-
ably covered by cumulates immediately after em-
placement and had little chance to move away from
mafic crystals at this horizon. Consequently, it is
suggested that the degree of separation of cumulus
mafic grains and feldspar during sedimentation was
a function of their height in the magma chamber just
after emplacement (excepting, of course, the possi-
bility of a thin chilled or rapidly crystallized layer
along the roof of the chamber in which all the early
phases were trapped as phenocrysts.

If this mechanism is correct, the top of the picrite
contains mafic cumulates which were near the roof
of the chamber just after emplacement. Olivine,
clinopyroxene, and labradorite at the bottom of the
picrite, however, probably did not move after em-
placement, and their modal ratio should represent
the ratio of these minerals in the magma on emplace-
ment. Good modal data on basal specimens are lack-
ing, but, roughly, labradorite appears to have been
a little more abundant than olivine and olivine about
twice the amount of clinopyroxene. The leucogabbro
layer consists of plagioclase which successfully sepa-
rated from the compacting cloud of mafic material.
However, a major problem not covered by this ex-
planation is the origin of the clinopyroxene in the
leucogabbro. It seems unlikely that clinopyroxene in
the leucogabbro was a member of the pre-emplace-
ment assemblage that failed to accumulate com-
pletely. Olivine occurs only in the basal layer, and
the difference in density of olivine and clinopyroxene
is not enough to suggest that the former mineral
should have settled more than the latter. The ap-
parent difference in shape of clinopyroxenes in the
leucogabbro and the picrite supports the view that
they did not crystallize together. Yet, it is not clear
why the composition of clinopyroxene from the two
layers is apparently similar if clinopyroxene in the
leucogabbro crystallized during or following accumu-
lation.

Considering that the sheet was probably not much
greater than 500 feet thick, the completeness of
accumulation of the mafic grains is remarkable. The
rate of settling of the cumulates must have vastly
exceeded the rate of crystallization of the liquid in
from the walls. In fact, the crystallization of the late
intercumulus assemblage apparently did not occur
until sedimentation was complete. The probable
high fluidity of the liquid phase during sedimenta-
tion greatly assisted the rapid settling.

Some aspects of the Shonkin Sag laccolith (Hurl-
but and Griggs, 1939) are similar to this intrusion.
The laccolith is also highly differentiated for a thin
body, and the color index of the lower shonkinite
layer increases upward. The mode of the chilled basal
layer of the Shonkin Sag body (47% phenocrysts)
indicates that the magma was rather crystalline on
emplacement. Unfortunately, petrographic coverage
of that body does not show whether or not cryptic
layering exists.

Origin of the Foliation

The feldspar fabric appears not to be primary but
to have formed by reorientation of feldspars in place.
Absence of prominent lineation of the feldspar and
lack of feldspar crystals stemming from a planar
surface indicate that this is not a growth fabric. The
fact that the foliation lies at high angles to the base
of the intrusion and the interface of the two layers
indicates that laminar flow of plagioclase tablets past
a planar surface did not cause alignment. It could be suggested that feldspar tablets were oriented during accumulation so that the tablets lay vertically. By this mechanism, however, the normals to the tablets should be randomly distributed in the horizontal plane rather than strongly aligned as shown in Fig. 4. Thus, the fabric could not have developed by sedimentation alone. As noted previously, the contrast between orthopyroxene textures in the foliate picrite of the layered body and in a non-foliate picrite a few miles south suggests that plagioclase alignment and orthopyroxene crystallization were contemporaneous. Finally, it is clear from the undeformed poikilitic texture of the late intercumulus kaersutite and titanobiotite that these minerals crystallized after the fabric had formed. Together, these points indicate that reorientation occurred after accumulation but before final consolidation.

Formation of a strong planar fabric by reorientation of crystals in a liquid requires that the abundance of crystals be high enough that differential movement of crystals and liquid can occur. A change of shape of the chamber is necessary for this differential movement. Figure 4 shows a definite relation between the preferred orientation in the igneous body and the attitudes of the bedding of the intruded metasediments. The bedding orientation is largely controlled by near-isoclinal overturned folds. The comparable orientation of igneous and country rock fabrics suggest that the foliation is an axial plane fabric and that the foliation resulted from deformation of the chamber in response to external stress.

The attitude of the fold axis defined by the base of the picrite roughly corresponds to attitudes of axes of major and minor folds in the surrounding rocks. This relation and the similar orientation of the igneous foliation and axial planes of folds in the country rocks suggest that intrusion occurred before regional deformation but that folding occurred before final consolidation of the igneous body.

The absence of protoclastic textures in these rocks indicates that reorientation occurred in a benign manner. It is suggested that the tabular grains were aligned by the flow of intercumulus liquid during deformation. The grains were reoriented by the moving liquid so that their largest surface lay in the plane of maximum liquid flow. The cumulus porosity of the rocks (12–25%) seems low compared to estimates from other cumulus rocks and to results of packing experiments (Hess, 1960; Wager et al. 1960). This supports the view that some of the intercumulus liquid was pressed out, but the poor sorting of these cumulates may also have yielded low porosities.

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