THE IGNEOUS ROCKS OF UTAH

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By

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Preface

The advancement in the knowledge of the chemical and physical laws controlling the behavior of solutions has been so rapid in recent years that they now cover a large field, and extend into nearly every department of science with which it is possible for them to be concerned. Among the most important branches that have been influenced greatest in the direction of making the observed facts harmonize with the theory of solutions,-is petrology. This subject is especially desirable as it presents phenomena outside of the physical and chemical laboratories. The facts as observed have not been produced by carefully arranged apparatus, but have been found ready made in nature.

Modern conceptions of the principles of physical chemistry have forced the petrologist to regard igneous magmas as solutions and to interpret the involved processes in accordance with these modern ideas. In the gradual change of the rock mass from the molten to the crystalline condition, the formation of mineral compounds, their separation from the residual magma, and their subsequent consolidation, must be accounted for upon the basis of the solution theory. Indeed, every stage through which it passes in reaching its final condition incorporates some phase or phases of the laws hither to referred.

The discussion which follows assums an elementary knowledge of the fundamental principles of petrology and various other branches of allied sciences.

In any line of identification it will be admitted that the greater the number of pecularities that can be determined, the more sure and accurate will the classification become. With this in view the writer has endevored to subject his rock specimens to both physical and optical methods of determination and to place them in their position in the petrographical series.

Contents

The Igneous Rocks of Utah.

Classification and Definition.--Although chemical and mineralogical composition and textures play an important role in the classification of rocks they are not genetically fundamental features. A differentce in properties produced by a difference in origin is the most common distinction of rocks and consequently becomes an excellent basis for classification.

Igneous rocks are produced by the solidification of molten masses that have existed within or upon the surface of the earth, and constitute the source from which all other types have been derived.

Sedimentary rocks are the indurated products of sedimentation. They therefore imply the existance of water as an agent in their formation.

Metamorphic rocks are formed from other types by the confluent action of heat and pressure. They are sometimes termed meta-sedimentary according to their pre-existing state.

Influence of Cooling on Texture.--- If the fall of temperature does not increase the viscosity beyond the mineral-forming condition, and the mass remains within the temperature limits of crystallization for all the constituent minerals, a granitoid texture will be produced. The magnitude of the component crystals will depend upon the rate of cooling, composition of the magma, and the pressure to which the mass has been subjected. In the case of granites the molten body has remained within the temperature limits of crystallization sufficiently long to allow the entire mass to crystallize. As this condition of constant temperature can obtain nowhere except at great depths, this type is of intratelluric origin. On the other hand sudden chilling produces

Microcrystallites and represents that class which results from rapid cooling. Glasses and their allies are derivitives from this process. Between these two extreme types there are many others, representing intermediate degrees in the cooling period.

Separation of Minerals from Solution.---The separation of minerals from solution depends upon the attainment of that degree of concentration necessary to saturate the solution. This concentration may be brought about in several ways: (1) by the introduction of a foreign substance; (2) by a change of pressure; (3) by a change of temperature; and (4) by the loss of one substance necessary to maintain equilibrium.

Order of Separation.---The order of separation is determined by the degree of saturation. That mineral with the highest degree of saturation will when the solution is cooled separate out first. The relative order of separation of the component minerals of a magma can be seen by investigating almost any series of thin sections. The following order is observed with but slight variation.--

(1) The iron minerals;

(2) The ferro-magnesium silicates;

(3) The feldspars;

(4) Quartz.

It is seen that this is the inverse order of their melting points. A question might arise as to the method of determining the order of crystallization. This difficulty is overcome when the fact is called to the mind that inclusions and idiomorphic crystals are earlier in point of origin than the surrounding material. In zonal structure the concentric fabric is well illus trative in giving one an idea of the relative age of minerals. By making a table with regards to inclusions the order can be very definitely established.

Crystallinity.---Complete crystallization of a molten mass results in the formation of a texture referred to as holocrystalline; partial crystallization as hypocrystalline. A glassy or vitreous texture is termed hyaline, complete and partial vitrification being denoted by holohyaline and hypohyaline, respectively. When the relative amounts of crystalline and glassy components are to be more definitely determined, this can be done by stating exactly the ratio between them. This system of classification may be employed. Percrystalline in which the ratio of crystals to glass is seven to one; docrystalline, from seven to one to five to three; hyalocrystalline, less than five to three and greater than three to five; dohyaline, less than three to five and greater than seven to one; perhyaline in which the ratio is less than one to seven.

Granularity. ---The size of the component crystals depends upon several factors such as, (1) the rate of cooling, (2) the molecular concentration of the mineral substances, These factors have an important bearing upon the size of the crystals, or granularity. When the crystalline forms attain a size perceivable with the unaided eye, the granularity is termed phanerocrystalline; when they are too small to be seen in this way, they are termed cryptocrystalline. Microcrystalline rocks are those in which the crystals are visible only with a microscope. In many cases crystal aggregates are too small to be seen even with the aid of optical appliances. These are cryptocrystalline.

Fabric.---The fabric, or pattern, of a rock is that factor of its texture which relates to the relative sizes of the crystals, their shapes and arrangements with respect to each other, and their relative abundance and distribution in a glassy or felsitic groundmass, if such is present. In practice it will be impossible to find a fabric composed of crystals of the same size. However it is possible to find an aggregate in which the crystals are of the same magnitude. Even this condition is seldom seen. Those crystals of the same magnitude which give character to the rock determine the fabric. Rock fabrics are divided into two classes; (1) equigranular--those composed of crystals of the same order of magnitude; and (2) enequigranular--those composed of crystals of different orders of magnitude. Other fabrics may be formed so as to present an interfingering effect. In this case one mineral extends into the other in long tongue-like masses which exhibit the same crystal orientation. Such are called graphic fabrics and occur chiefly in conection with quartz and feldspar.

Shapes of Crystals.---Crystals may be described with respect to shape, and these forms will depend upon the bounding surfaces and the relative dimentions of the limiting planes. Classification with respect juxta position and intraposition is as follows: (1) euhedral, well faced and bounded by crystal planes; (2) subhedral, crystals partially faced and partially bounded by crystal planes; and (3) anhedral, not faced and without crystal planes.

Differentiation. --- The term differentiation has a much broader significance with respect to rock magmas than is usually considered. Large masses separate into distinct portions with refference to:(1) composition, and thus thus develope the different minerals; and (2) place of occurrence and time of eruption. In the case of narrow necks or dykes of igneous rocks the may be rich in certain minerals which are almost wholly absent in the center of the body. Some magmatic segregations seem to be produced regardless of the form or boundary of the adjacent formation and are composed of heteromeneous masses evidently extruded in place; or there may be in the body large xenoliths resembling the adjacent country rock.

Petrographic Provinces.---It is a note worthy fact that well defined provinces exist upon the earth as a whole marked chemical and mineralogical differences may obtain the rock series of two regions. The boundary may be well defined or the rocks of one region may pass gradually into those of another. There are several grand divisions of igneous rock each of which has its own characteristic facies. The difference may consist in silica percentage, kinds of minerals, nature of formations, and order of eruption; any factor of which being emphasized above the others may produce a distinct type. Along the Pacific coast of North America the eruptive rocks have an average composition, being normally rich in the alkali feldspars, lime, magnesia, and iron. Extending eastward from the Rock Mountains the feldspars become more abundant and the feldsphathoids assume importance as mineral components. In the respective groups certain related pecularities exist, showing a probable derivation from the same magmatic mass. It must also be understood that in the case in which the facies of two provinces are similar for like structures that the nature of the body with respects to shape has an important bearing upon the mineralogical composition.

Order of Eruption.--No special order as to acidic or basic eruptions can be predicted with certainty, for there is no reliable evidence upon this question. Acidic eruptions may follow basic ones or vice versa. But the significant fact to be kept in mind is that the initial products have in general an average composition, while the later flows become more and more separated in point of similarity untill the final eruption presents rocks of the most diverse types.

Factors Involved in Differentiation.---If a given magma can be made to vary with regard to segregation a great step in the direction of determining the various factors involved in the process, can be taken; for the discovery of what produces variation in a phenomena is an indication of what causes the fact in the first place. When related forms of igneous bodies are investigated as to thier external conditions, relative time of eruption, and the nature of the residual mass, valuable criteria for determining the causes of differentiation are given. Differentiation may be brought about in three general ways: (1) external environment and the change of position may produce different end results, because with a change of position there comes a change of environment. Hence the same magmatic reservoir may give rise to several somewhat different products; (2) geologic processes are continuous and differentiation is no exception. Time of course is necessary for the magma to become segregated into phases and the character of an eruption will depend upon the nature of the phase attained at that time. Then again since the reservoir contains masses at different temperatures and compositions the relative position and size of the vent will influence the extruded portion; (3) differentiation subsequent to the initial separation from the parent reservoir produces wide differences in composition. If the mass consolidates immediately after being drawn off from the parent magma then its composition will represent the particular phase attained at that time by the original body. But this in general does not take place. Even after being injected into a fissure or conduit the mass differentiates even more rapidly than before on account of being near the surface and in a region of greater changes in temperature and loss of gas content. Moreover, the environment may differ for different tongues, and introduce in this way a still wider degree of variation. So we see that these conditions introduce complex end results in the process of differentiation.

Differentiation Depending upon Internal Changes.---Some writers object to these conditions upon the grounds that they are inadequate to produce the great results found in these rock masses. However, no one can doubt that the following factors have their effects though one may call into question the extent of these effects

(1) The density of the liquid, a variation of which is responsible for the convection currents set up.

(2) The molecular Concentration.

(3) The saturation producing crystallization in different parts.

(4) The viscosity, determining the rate of diffusion.

(5) The chemical equilibrium, affecting precipitation and the production of mineral compounds.

(6) The solidification, affecting the texture of the resulting rock.

Structures of Igneous Rocks.---Since igneous rocks consolidate either upon the surface or at depths, the forms in which they occur ean be referred to as extrusive or intrusive bodies.

Extrusive Forms.---The most common extrusive calss is the lava sheets. The liquid emenates from lenticular fissures or more or less cylindrical pipe and spreads out over large areas. Conduits may lead from the same magmatic reservoir and widely different products. Some may be viscous, others fluid and watery, each giving rise to special products. The viscous or acid type will run slowly and quickly form a thick crust which breaks up and becomes incorporated within the stream as angular fragments. The basic class is generally very fluid and moves rapidly, as a result of which a thin crust is formed and very little fragmental material is encountered. The escaping of the gasses produces vesicular and pumeceous structures, the vesicles being elongated in the direction of flow. Lava streams descending a slope may assume ropy contortions, or dome-like masses.

Domes fequently occur as structures in connection with lava flows. In this case the viscosity is so great that material remains about the vent and piles up into more or less dome-shaped bodies.

A magma may have a density sufficiently high to support large crystalline masses. If then these bodies be extruded to the surface they may project up through the crust of the earth and produce spines.

Intrusive Bodies.---It is a notable fact that igneous activity is almost entirely absent in the locality where the strata are horizontal, and occur in greater abundance im places where the strata are tilted and fractured. In the first case the sedimentary formations are extremely thick and practically free from deep-seated fissures and shearing zones, which materially lessen the resistance of the overlying beds. Along these planes of weakness the igneous masses make their way, disolving, thrusting aside, and fracturing the barriers. The nature of the body will depend upon the character and conditions of the effected country rock.

Dikes.---In cases where fissures are filled with molten rock, the width of these fissures being great in propoxtion to their length, the resulting forms are dikes. Veins are smaller and transect small areas.

Stocks, Cores and Necks are vertical pipes filled with solidified molten magmatic material. Since such forms occur without respect to fissures and seem not to have been greatly influenced by their presence, it is supposed that the circular pipes have been produced by explosions and given vent to contained gases.

Intrusive sheets are in the main horizontal, having been formed in relation to sedimentary strata; the magma has been intruded between the beds in thin sheets, raising the superposed rocks to a variable degree.

When the resistance to separation offered by the sedimentary beds counter balances the tendency of the intrusive mass to thrust these beds apart, then a lifting of the centrally situated strata will occur and there will be produced a large deep-seated, ovate igneous body known as a laccolith.

The bysmaliths are formed from plugs of molten magma that have been thrust more or less vertically into the superincumbent beds. as a rule they do not reach the surface. They have extremely vertical dimensions and are accompanied by vertical faulting. The superincumbent rocks have been lifted at one time, and the act of thrust of the magmatic mass has been sudden and continuous. Stocks on the contrary are the results of the filling and pushing aside of the overlying beds.

Batholiths are intrusive bodies traversing country rock without respect to structure or composition. They closely resemble stocks.

Part II.

Granite

Slide No. 1.--C. M. N. 1912. Locality,-Newhouse, Utah. Cactus Mine.
Rock No. 2541 Age.-Carboniferous
Plate I. Fig1.
Variety.--Tourmaline, pegmatitic; mass brecciated and fractures filled with tourmaline, hence a secondary mineral.
Crystallinity.--Holocrystalline.
Granularity.--Cryptocrystalline.
Fabric.--Inequigranular, poikiltic.
Shapes of Crystals.--

Tourmaline: euhedral, tabular, prismatic, radiating and fibrous, parting parallel to base.

Quatrz: anhedral, similarly oriented.

Orthoclase: Anhedral, similarly oriented and partially decomposed to kaolin.

Zircon:-as inclusions in quartz.

Pegmatite.

Pegmatite.

Slide No. 2.--C. M. N. 1912.   Locality.-Antelope Island,
Great Salt Lake.

Rock No. 10-7-4-1   Age.-Precambrian.

Plate I. Fig. 2.

Variety.--Quartz Pegmatite.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline, except in isolated parts and there microscopic scales developed.

Fabric.--Inequigranular, seriate, intersertal; pegmatic structure not shown in slide but seen in rock specimen.

Shapes of Crystals.--Anhedral and irregular for all components.

Minerals.--Quartz; orthoclase, altered; plagioclase, altered; alteration products carried away and replaced by hematite and serpentine.

Obsidian.

Slide No. 3.--C. M. N. 1912.   Locality.-Iron County, Utah.

Rock No. 12233

Plate I. Fig. 3.

Variety.-- Black with concoidal fracture.

Crystallinity.--Holohyaline

Special features.--Flowage well marked; crystallites microscopic; extremely sudden cooling.

Latite.

Slide No. 6.--C. M. N. 1912.   Locality.-Rabbit Valley, Wayne Co., Ut

Rock No.

Plate I Fig. 5.

Variety.--Augite Latite.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular- hiatal.

Shapes of Crystals.--Euhedral, equiform.

Groundmass.--Diabasic texture composed of microscppic minerals.

Resorbtion.--In orthoclase and plagioclase.

Alteration.--In augite to hematite and magnetite, preservation of the form of the original mineral.

Minerals, Pyrogenetic.--Orthoclase, augite, zircon, plagioclase and nephelite.

Minerals, Secondary.--Magnetite, hematite and limonite.

Gabbro

Slide No. 7.--C. M. N. 1912. Locality.-Camp Floyd, Utah.

Rock No, Age.-Not determined.

Plate I. Fig. 7.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral, subhedral and anhedral, depending upon its specific mineral.

Minerals.--Hornblende, green and basic; augite; olivine; plagioclase; magnetite; orthoclase; zircon; biotite; chlorite and serpentine.

Pegmatite

Slide No. 8.--C. M. N. 1912. Locality.-Antelope Island Great Salt Lake.

Plate.--Not photographed.

Variety.--Quattz orthoclase.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Subinequigranular, hiatal.

Shapes of Crystals.--Anhedral, irregular.

Minerals.--Quartz, closed structure; orthoclase.

General Features.--Pegmatitic texture is not showm here but is observable in hand specimen.

Monzonite.

Slide No. 9.--C. M. N. 1912. Locality.-Near Milford, Utah.

Rock No.--Not in museum.

Plate.-Not Photographed.

Variety.--Quattz monzonite.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Minerals.--Quartz; orthoclase; biotite; hornblende; magnetite; albite; zircon; chlorite.

General Features.--Scaly aggregates of chlorite appear as alterations of feldspars; magnetite occurs as inclusions in the biotite and hornblende; zircon is distributed in both pyrogenetic and secondary minerals.

Rhyolite.

Slide No. 10.--C. M. N. 1912. Locality.-Weber Co., Utah.

Rock No. 1434 Age.-Unknown.

Plate.Not photographed.

Variety.--Common.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral, irregular.

Minerals.--Orthoclase altered to kaolin and partially resorbed; quartz, fresh; hornblende; magnetite; and biotite.

Remarks.--The groundmass is glassy and presents a perlitic structure; no flowage is apparent.

Obsidian.

Slide No. 11.--C.M.N. 1912. Locality.-State Line,Utah.

Rock No. 1215. Age.-

Variety.--Concretionary, slightly.

Crystallinity.--Holocrystaline.

Remarks.--A slight suggestion toward perlitic structure is presented; flowage well shown; minute fractures exist throughout the entire mass.

Rhyolite.

Slide No. 12.--C. M. N. 1912. Locality.-Stateline, Utah.

Rock No. Age.-

Plate II. Fig. 1.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Anhedral, subhedral, and euhedral, equant equiform

Remarks.--Excellent flowage, microcrystallites abundant.--
Incipient crystallization.

Minerals.--Quartz, nephelite, orthoclase hornblende, magnetite, zircon and augite.

Pitchstone.

Slide No. 13.--C. M. N. 1912. Locality.-Dugway Mts., Utah.

Rock No. Age.-

Plate II. Fig. 2.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral, showing sometimes resorbtion and alteration and fractures.

Granite.

Rock No. 2252 Age.-PostCambrian to PreCretaceous.

Slide No. 14.--C. M. N. 1912. Locality.-Cottonwood Canyon, Utah.

Plate II. Fig.3

Variety.--Biotite Granite. (2 Micas)

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal, poililtic.

Shapes of Crystals.--Anhedral, euhedral, and subhedral.

Dimensions of Crystals.--Irregular and closed.

Minerals.--(a) Pyrogenetic: orthoclase, quartz, biotite, plagioclase, augite, magnetite, zircon, hornblende, and apatite.

(b) Secondary: kaolin, serpentine and chlorite.

Remarks.--Zircon is held as inclusions in biotite. hornblende and feldspar, hence a poikiltic structure with zircon and magnetite as phenocrysts is presented.

Andesite.

Slide No. 15.--C. M. N. 1912. Locality. Big Cottonwood Canyon, Utah.
Rock No. 7254. Age.-Unknown.
Plate.--Not photographed.
Variety.--Common.
Crystallinity.--Hypocrystalline.
Granularity.--Micfocrystalline.
Fabric.--Inequigranular, hiatal.
Shapes of Crystals.--Euhedral and subhedral.
Dimensions of Crystals.--Equiform.
Minerals.--(a) Pyrogenetic; biotite, magnetite, zircon, sphene, apatite.
(b) Secondary: kaolin, chlorite and serpentine.
Remarks.--The ground mass composed wholly of plagioclase is completely altered to kaolin with, however, the preservation of the original twinning of the feldspar. In transecting all minerals zircon has evidently been the first mineral to crystallize from the magma. Biotite and hornblende have altered to serpentine.

Trachyte.

Slide No. 16.--C. M. N. 1912. Locality.-South of Alta, Utah.
Rock No. Age.-PostCambrian to PreCretaceous.
Plate.--Not photographed because of almost complete alteration.

Variety.--Common.

Crystallinity.--Amorphous.

Granularity.--Microcryptocrystalline.

Fabric.--Inequigranular, seriate, porphyroid in patches.

Shapes of Crystals.--Euhedral, irregular.

Dimensions of Crystals,--Multiform.

Minerals.--(a) Orthoclase, magnetite, and chlorite.

Remarks.--The ground mass consisting chiefly of chlorite is finely impregnated with minute crystals of magnetite.

Trachyte.

Slide. No. 17.--C. M. N. 1912. Locality. Southeast of Alta, Utah.

Rock No. Age.--PostCambrian to PreCretaceous.

Plate.--Not photographed.

Variety.--Hornblende.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystalls.--Irregular, subhedral and multiform.

Minerals.--(a) Primary: Orthoclase, hornblende, magnetite, zircon and apatite.

(b) Secondary: Limonite, chlorite and serpentine.

Remarks.--The most interesting feature of this section is the high degree of alteration of the hornblende to serpentine, the orthoclase to chlorite and the staining of certain portions by limonite.

Trachyte.

Trachyte.

Slide No. 18.--C. M. N. 1912. Locality.-Dyke West of Alta, Utah.

Rock No. Age.-Post-Cambrian to Pre-Cretaceous.

Plate II. Fig. 4.

Variety.--Augite Trachyte.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Idiomorphic and hypoidiomorphic.

Dimensions of Crystals.--Prismoid and irregular.

Minerals.--(a) Primary: orthoclase, hornblende, magnetite, apatite, zircon and augite.

(b) Secondary: chlorite, magnetite, serpentine and hematite

Remarks.--The augite has partly altered to magnetite, hornblende to serpentine and the feldspar to chlorite.

Syenite.

Slide No. 19.--C. M. N. 1912. Locality.-East of Alta, Utah.

Rock No. Age.-Pre-Cambrian.

Variety.--Hornblende Syenite.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline.

Fabric. Inequigranular, hiatal.

Shapes of Crystals.--Euhedral, subhedral and anhedral.

Dimensions of Crystals.--Irregular and equant.

Minerals.--(a) Primary: orthoclase, plagioclase, hornblende, apatite, magnetite, zircon and biotite.

(b) Secondary: chlorite and serpentine.

Remarks.--Subsequent to the formation of the hornblende, resorbtion took place redisolving this mineral and giving way to orthoclase. Zircon is found distributed almost uniformily throughout the entire mass. Hornblende has also alterated to magnetite.

Trachyte.

Slide No. 20.--C. M. N. 1912. Locality.-Eureka, Utah.

Rock No. Age. - Pre-Carboniferous.

Variety.--Common.

Crystallinity.--Hypocrystalline.

Granularity.--Microcrystalline.

Fabric.--Equigranular.

Shapes of Crystals.--Euhedral, equent.

Minerals.--(a) Primary: Orthoclase.

(b) Secondary: chlorite and limonite.

Remarks.--The groundmass consists of a chlorite aggregate with minute grains of iron.

Trachyte.

Slide No. 21.--C. M. N. 1912. Locality.-¼Mile East of Alta, Utah.

Rock No. Age. - Post-Cambrian.

Variety.--Common.

Crystallinity.--Hypocrystalline.

Granularity.--Crytocrystalline.

Fabric.--Inequigranular, serate porphyroid.

Shapes of Crystals.--Subhedral and euhedral.

Minerals.--(a) Primary: orthoclase and magnetite.

(b) Secondary: chlorite and iron.

Remarks.--The mass appears to have been fractured and the crevices filled with secondary iron minerals.

Scoria.

Slide No. 22.--C. M. N. 1912. Locality.-Millard County, Utah.

Rock No.1212. Age.--Recent.

Plate II.Fig.5.

Variety.--Basic Scoria.

Remarks.--The entire mass consists essentially of microscopic crystals of plagioclase and hornblende, arranged so as to present a diabasic texture. There are also phenocrysts of plagioclase.

Trachyte.

Slide No. 23.--C. M. N. 1912. Locality.-Wasatch, Utah.

Rock No. Age.-- Post-Cambrian.

Variety.---Common.

Crystallinity.--Hypocrystalline.

Granularity.--Cryptocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral, subhedral and anhedral.

Dimensions of Crystals.--Prismoidal and irregular.

Minerals.--(a) Primary: orthoclase, biotite, magnetite, hornblende, zircon and apatite.

(b) Secondary: chlorite,serpentine and ferric iron.

Remarks.--The rock has suffered extensive alteration and is stained throughout with ferric oxide. After the formation of hornblende crystals the magma was subjected to strain. Pegmatic structure is shown in patches.

Trachyte.

Slide No. 24.--C. M. N. 1912. Locality.-Weber Canyon, Utah.

Rock No. Age.-- Post-Carboniferous.

PlateIII. Fig. 1.

Variety.--Common.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral, subhedral.

Dimensions of Crystals.--Irregular, equant, triangular and prismoid.

Minerals.--(a) Primary: orthoclase, hornblende, augite, magnetite and biotite.

(b) Secondary: chlorite and limonite.

Remarks.--The augite is badly fractured and altered to magnetite and the ferric oxide of iron. The orthoclase is altered in places to chlorite. The hornblende is sometimes found as inclusions within the orthoclase and partly replaced by it. Minute crystals of sphene are distributed throughout the mass. Zircon occurs both in the ground mass and phenocrysts.

Rhyolite.

Slide No. 25.--C. M. N. 1912. Locality.-Eureka, Utah.

Rock No. Age.-

Variety.--Hornblende Rhyolite.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Minerals.--(a) Primary: Biotite, hornblende, magnetite and orthoclase.

(b) Secondary: chlorite and ferric iron.

Trachyte.

Slide No. 26.--C. M.N. 1912. Locality.-North of Heber, Utah.

Rock No. Age.-Unknown.

Plate II. Fig. 6.

Variety.--Hornblende Trachyte.

Crystallinity.--Hypocrystallinity.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal, poikiltic.

Shapes of Crystals.--Irregular, equant.

Groundmass.--Sempatic.

Minerals.--(a) Primary: orthoclase, hornblende, biotite and zircon.

(b) Secondary: chlorite, hematite and serpentine.

Remarks.--Zonal structure in orthoclase well marked: oikocrysts of zircon as chadacrysts exists in most minerals. Mass unusually rich in basic hornblende.

Rhyolite.

Slide No. 27.--C. M$\frac{3}{4}$ N. 1912. Locality.-State Line, Utah.

Rock No. Age.-- Post-Carboniferous.

Plate III. Fig. 2.

Variety.--Nephelite Rhyolite.

Crystallinity.--Hupocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular.

Shapes of Crystals.--Euhedral/

Minerals.--(a) Primary: Quartz, orthoclase, sanadin, nephelite, magnetite and zircon.

(b) Secondary:

Remarks.--Groundmass sempatic; flowage well shown, incipient crystallization well shown by microcrystallites.

Andesite.

Slide No. 28.--C. M. N. 1912. Locality.-Rabbit Valley, Wayne Co. Ut.

Rock No. 5112. Age.-

Plate III. Fig. 3.

Variety.--Augite Andesite.

Crystallinity.--Hypohyaline.

Granularity.--Semi-phanerocrystalline.

Fabric.--Diabasic, inequigranular, hiatal.

Shapes of Crystals.--Euhedral, equiform.

Minerals.--(a) Primary; orthoclase, plagioclase, augite, magnetite, garnet and zircon.

(b) Secondary: hematite and magnetite.

Remarks.--Resorbtion of the feldspar is well shown. The partial alteration of augite to hematite is a significant feature.

Rhyolite.

Slide No. 30.--C. M. N. 1912. Locality.-Eureka, Utah.

Rock No. 1623. Age.-Cretaceous.

Plate.--Not photographed.

The specimen is badly altered, the orthoclase to kaolin and chlorite; fragments of hornblende and biotite are distributed throughout the rock.

Trachyte.

Slide No. 31.--C. M. N. 1912. Locality.-Snake Creek near Midway, Ut.

Rock. No. 5412. Age.--Carboniferous.

Variety.--Hornblende Trachyte.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Irregular, hiatal.

Shapes of Crystals.--Irregular, fractured, equiform and equant.

Minerals.--Orthoclase, plagioclase, hornblende, magnetite, apatite, zircon, biotite, chlorite, hematite and sphene.

Remarks.--Zonal structure, cross turning and alteration in the feldspars are well marked. Hornblende is partially altered to serpentine and hematite and perhaps magnetite. The oikocryst is microcrystalline. Biotite carries zircon as inclusions.

Trachyte.

Slide No. 32.--C. M. N. 1912. Locality.-3½ Miles Northwest of Heber Utah.

Rock No.--3413. Age.-Unknown.

Plate III. Fig. 4.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal, porphyroid and sempatic.

Shapes of Crystals.--Euhedral, subhedral and anhedral.

Mineral.--Orthoclase, magnetite, zircon, apatite, biotite, hornblende, sphene and chlorite.

Special Features.--Zonal structure, basal sections of hornblende, rich in apatite and zircon.

Trachyte.

Slide No. 33. C. M. N. 1912. Locality.-Tintic, Utah.

Rock. No. 3422. Age.-Unknown.

This rock consists of badly altered feldspar and hornblende.

Rhyolite.

Slide No. 34.--C. M. N. 1912. Locality.-Eureka, Utah.

Rock No. 5122. Age.-Post-Cambrian.

Plate III. Fig. 5.

Variety.--Common.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.--

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Irregular.

Minerals.--Orthoclase, quartz, magnetite, biotite and hornblende.

Remarks.--Rock is badly altered to chlorite and kaolin.

Monzonite.

Slide No. 35.--C. M. N. 1912. Locality.-Eureka, Utah.

Rock No. 3423. Age.-Post-Cambrian.

Plate III. Fig. 6.

Variety.--Common.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Hiatal, inequigranular, sempatic.

Shapes of Crystals.--Euhedral and anhedral.

Minerals.--Orthoclase, plagioclase, biotite, hornblende, serpentine, kaolin, chlorite, hematite and apatite.

Rhyolite.

Slide No. 36.--C. M. N. 1912. Locality.-One Mile North of Heber, Ut.

Rock No. 1523. Age.--Unknown.

Plate IV. Fig.1.

Variety.--Hornblende Rhyolite.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral.

Dimensions of Crystals.--Prismatic, irregular, triangular, equiform, elongate and elliptical.

Minerals.--Orthoclase, quartz, biotite, hornblende, apatite, plagioclase, magnetite, hematite and zircon.

Remarks.--Zonal structure on magnificent scale; basic sections of hornblende well shown, apatite in basic and parallel sections.

Lava.

Slide No. 39.--C. M. N. 1912. Locality.-Eureka, Utah.

Rock No. 1243. Age.-Post-Cretaceous.

Plate IV. Fig. 3.

Variety.--Diabasic Lava.

Crystallinity.--Hyalocrystalline.

Granularity.--Cryptocrystalline.

General Features.--The rock has been highly altered, the orthoclase crystals decomposing into chlorite. The crystals of feldspar arranged so as to produce a diabasic texture.

Latite.

Slide No. 41.--C. M. N. 1912. Locality.-Beaver County, Utah.

Rock No. 3313. Age.-Unknown.

Plate IV. Fig, 5.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal, sempatic.

Shapes of Crystals.--Euhedral.

Minerals.--(a) Primary: orthoclase, plagioclase, hornblende, biotite and zircon.

(b) Secondary: Magnetite, serpentine and ferric iron.

Remarks.--Biotite is altered to serpentine, hornblende to magnetite; spherulitic structure.

Rhyolite.

Slide No. 42.-C. M. N. 1912. Locality.-Ophir, Utah.

Rock No. Age.-Post-Carboniferous.

Crystallinity.--Holocrystalline.

Granularity.--Cryptocrystalline.

Fabric.--Inequigranular, seriate porphyroid.

Shapes of Crystals.--Euhedral and anhedral.

Minerals.--(a) Primary: Orthoclase, quartz and magnetite.

(b) Secondary: chlorite and iron stain.

Remarks.--The rock is so very badly decomposed that few primary minerals are shown. The feldspar is almost completely altered nto chlorite. The iron stain is due to decomposition of some pyrogenetic iron mineral, perhaps magnetite.

Trachyte.

Slide.No. 43.--C. M. N. 1912. Locality.-Beaver County, Utah.

Rock No. 3323. Age.- Post-Cambrian.

Plate IV. Fig. 6.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral and subhedral.

Minerals.--(a) Primary: biotite, orthoclase, zircon, hornblende, plagioclase, magnetite augite, apatite, nephelite and titanite.

(b) Secondary: serpentine, magnetite, chlorite and kaolin.

Remarks.--The mass shows a high degree of resorbtion of hornblende, and a marked alteration to serpentine and magnetite. Spherulitic and hiatal structure are perhaps the most significant features of this rock. The greenish groundmass is serpentine.

Diorite.

Slide No. 44.--C. M. N. 1912. Locality.-Frisco, Utah.

Rock No. 8414. Age.-Unknown.

Not Photographed.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, seriate porphyroid.

Shapes of Crystals.--Euhedral, subhedral and anhedral.

Minerals.--(a) Primary: Zircon, plagioclase, magnetite, apatite, olivine and sodalite.

(b) Secondary: serpentine, chlorite and kaolin.

Remarks.--This rock is badly decomposed dolerite. The magnetite is somewhat vesicular, perhaps due to resorbtion or partial decomposition.

Vitrophyre.

Slide No. 45.-C. M. N. 1912. Locality.-Iron County, Utah.

Rock No. 1254. Age.-Recent.

Plate V. Fig. 1.

Crystallinity.--Hyalocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.--Euhedral or idiomorphic.

Minerals.--(a) Primary: garnet, orthoclase, plagioclase, biotite, hornblende, magnetite, nephelite and zircon.

(b) Secondary: limonite and magnetite.

Remarks.--This rock exhibits excellent flowage, the magma has consolidated while the crystals were in suspension. The mass during the flowage was highly viscus, so viscus that some of the feldspar crystals were fraatured and torn apart. Garnet showing double refaction is present in a somewhat altered condition.

Rhyolite.

Slide No. 46.-C. M. N. 1912. Locality.-Ophir, Utah.

Rock No. Age.Post-Carboniferous.

Plate. V. Fig. 2.

Crystallinity.-- Hypocrystalline.

Granularity.--Phanerocrystalline and cryptocrystalline.

Fabric.--Inequigranular.

Shapes of Srystals.--Euhedral.

Dimensions.--Irregular and equiform.

Minerals.--(a) Primary: quartz, magnetite, orthoclase, zircon, apatite and muscovite.

(b) Secondary: Chlorite, serpentine, chlorite and sericite.

Remarks.--A good example of resorbtion in quartz is here seen; also large apatite crystals showing basal cleavage. The orthoclase has altered to chlorite and the ferro-magnesium silicates to serpentine.

Andesite.

Slide No. 47.-C. M. N. 1912. Locality.-Ophir, Utah.

Rock No. 5431. Age.- Pos-Carboniferous.

Variety.--Biotite-Magnetite Andesite.

Crystallinity.--Hypocrystalline.

Granularity.--Cryptocrystalline.

Fabric.--Inequigranular, poikiltic, spherulitic.

Shapes of Crystals.--Senticular and equilateral, presenting a spotted appearance.

Minerals.--(a) Primary: biotite, magnetite, plagioclase, orthoclase and hornblende.

(b) Secondary: serpentine, chlorite and limonite.

Remarks.--This rock is very finegrained presenting a spotted spherulitic fabric.

Trachyte.

Slide No. 51.-C. M. N. 1912. Locality.-Little Cottonwood Canyon, Ut

Rock No. Age.-Post-Cambrian.

Variety.--Hornblende Trachyte.

Crystallinity.--Hypocrystalline.

Granularity.--Cryptocrystalline.

Fabric.--Hiatal.

Shapes of Crystals.--Euhedral.

Minerals.--Hornblende, orthoclase, kaolin, zircon. apatite, biotite, chlorite and magnetite.

Remarks.--This presents a typical hiatal fabric. Beautiful zonal structure in orthoclase is well shown. Zircon as oikocrysts is found in the crystals of hornblende and orthoclase.

Granite.

Slide No. 52.-C. M. N. 1912. Locality.-Beaver County, Utah.

Rock No. 3814. Age.-Unknown.

Variety.--Microcline Granite.

Crystallinity.--Holocrystallinity.

Granularity.--Phanerocrystalline.

Fabric.--Crystals arranged in juzta-position.

Shapes of Crystals.--Subhedral and anhedral.

Minerals.--Quartz, orthoclase, microcline, alibite, hematite, zircon, olivine and hornblende.

Remarks.--Some of the crystals in this section are held together by ferric oxide acting as a cement. The hornblende has been almost completely altered to the hematite. Carbon dioxide inclusions are somewhat numeraus.

Trachyte.

Slide No. 53.-C. M. N. 1912. Locality.-Beaver Lake, Utah.

Rock No. 3352. Age.-Unknown.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.-- Hiatal.

Shapes of Crystals.--Euhedral.

Minerals.--(a) Primary: orthoclase, biotite, hornblende, apatite, zircon, magnetite, sphene, garnet and muscovite.

(b) Secondary: hematite, kaoline, serpentine and chlorite.

Remarks.-- Although this rock seems to be highly altered well preserved basal sections of hornblende appear. There is also an example of twinning in hornblende.

Andesite.

Slide No. 54.-C. M. N. 1912. Locality.-Silver Reef, Utah.

Rock No. 7353. Age.-Unknown.

Variety.--Augite Andesite.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Hiatal.

Shapes of Crystals.--Idiomorphic.

Minerals.--(a) Primary: alibite, orthoclase, magnetite, augite, biotite, hornblende, zircon and apatite.

(b) Secondary: magnetite, chlorite kaolin and hematite.

Remarks.--This is one of the most typical andesites that will ever be met with. Note the twin crystals of augite, finely laminated plagioclase and the CO_2 inclusions.

Granite.

Slide No. 58.-C. M. N. 1912. Locality.-Millard County, Utah.

Rock No. 2724. Age.-Unknown.

Plate VI. Fig. 2.

Variety.--Hornblende Granite.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Equigranular.

Shapes of Crystals.--Euhedral, subhedral and anhedral.

Minerals.--Quartz, orthoclase, hornblende, plagioclase, microcline, apatite and zircon.

Remarks.--This rock is especially interesting on account of the abundance of microcline and isolated patches of micrographic intergrowth between quartz and feldspar. It has almost enough plagioclase to be classed as a quartz diorite.

Tonolite.

Slide No. 60.-C. M. N. 1912. Locality.-Copper Canyon, Frisco, Ut.

Rock. No. 6211. Age.-Unknown.

Variety.--Common.

Crystallinity.-- Holocrystalline.

Granularity.--Cryptocrystalline.

Fabric.--Seriate porphyroid.

Shapes of Crystals.--Anhedral.

Minerals.-- Andesine, quartz, mica.

Remarks.--A tonolite is a quartz-mica-diorite the principal feldspar of which is andesine.

Andesite.

Slide No. 62.-C. M. N. 1912. Locality.-Ophir, Utah.

Rock No. Age.- Post-Carboniferous.

Plate VI. Fig. 4.

Variety.--Hornblende Andesite.

Crystallinity.--Hypocrystalline.

Granularity.--Cryptocrystalline.

Fabric.--Irregular, hiatal, approaching diabasic.

Shapes of Crystals.--Elongate.

Minerals.--Plagioclase, biotite, hornblende, magnetite, muscovite.

Trachyte.

Slide No. 65.-C. M. N. 1912. Locality.-Heber, Utah.

Rock No. Age.- Post- Carboniferous.

Plate VI. Fig.5.

Variety.--Hornblende Trachyte.

Crystallinity.--Holocrystalline.

Granularity.--Phanerocrystalline, and cryptocrystalline.

Fabric.--Irregular, seriate porphyroid.

Shapes of Crystals.--(a) Oikocrysts: prismoids, regular, elongate, equant, euhedral, subhedral and anhedral.

(b) Chadacrysts: anhedral.

Minerals.--Hornblende, orthoclase, apatite, magnetite, biotite, zircon, chlorite and serpentine.

Scoria.

Slide No. 72.-C. M. N. 1912. Locality.-Fillmore, Utah.

Rock No. 1212. Age.- Post-Jurassic.

Plate VII. Fig. 6.

Variety.--Cellular lava, basic type.

Remarks.--Distributed throughout this rock are found small but well developed crystals of orthoclase, showing that at the time of extrusion the molten mass contained these crystalline forms. The escaping gases have produced the cellular structure.

Trachyte.

Slide No. 76.-C. M. N. 1912. Locality.-Park City, Utah.

Rock No. Age.- Post-Carboniferous.

Variety.--Basic Hornblende Trachyte.

Crystallinity.--Hypocrystalline.

Granularity.--Phanerocrystalline.

Fabric.--Inequigranular, hiatal.

Shapes of Crystals.-Euhedral.

Minerals.--(a) Pyrogenetic: orthoclase, hornblende, magnetitem sphene, biotite, plagioclase and apatite.

(b) Secondary: hematite and kaolin.

Remarks.--Excellent idiomorphic crystals of hornblende are here shown, also sphene twins.

Part III. Rock Types.

Glasses.-- Since the most extreme variations in the temperature obtain at the surface of the earth, and since this surface is much colder than the molten masses ejected upon it from the interior, sudden and very rapid cooling takes place in all ejectamenta; so rapid does the fall of temperature occur that the narrow limits between incipient crystallization and viscosity-that range through which the mass crystallizes-is passed so quickly that the minerals if they form at all are rare and fragile. Rock types formed from the consolidation of surface flows are therefore termed glasses because of their amorphous nature. Obsidian, perlite, pitchstone, pumice, tachylyte, and scoria are the principle varieties.

Obsidian is a dark vitreous rock with conchoidal fracture. In thin sections well defined lines of flowage are usually present. It often hapens that the cooling in glasses is of such a nature as to produce a rough approach to concentricity in structure. Rocks of this type are known as perlites. Pitchstones present a resinous appearance. Fine loosely compact volcanic material is known as pumice. Tachylyte is a basaltic obsidian or perlite. It is well known that all magmas are highly impregnated with gasses and that when the molten material reaches the surface these gaseous products are expelled leaving the original rock full of vesicules. Vesicular masses of this kind are known as scoria.

Rhyolites and Related Groups.--Acidic magmas that have not had sufficient time for compleat crystallization give rise to Rhyolites, or liparites. Quartz, orthoclase, biotite, and hornblende are the essential minerals. If in addition to these there are phenocrysts of augite, sanadin, and aegarite, the rhyolite becomes a comendite. The groundmass may be either glassy or felsitic.

Granites and Related Groups.--In granites the component crystals produce a closed or holocrystalline texture, that is the minerals are arranged so as not to possess their own boundaries. The essential minerals besides the orthoclase feldspars are quartz biotite and muscovite. It sometimes happens that the rock contains two micas in which case it is known as a binary-granite. Associated with these minerals are usually small quanities of hornblende, plagioclase, augite, zircon, magnetite, apatite, garnet, tourmaline, titanite and epidote. Granites differ from rhyolites in texture only.

Trachytes and Related Groups.--The essential minerals in the trachytes are biotite,hornblende and augite and orthoclase, while the accessory minerals are plagioclase, apatite, zircon, tourmaline, aegarite, and magnetite. The texture here is felsitic to porphyritic. The only difference between this and the rhyolites is the absence of quartz in the former. Trachytes differ from granites in texture and the amount of free quartz.

Syenites and Related Groups.--The chief felspar of this group is orthoclase,and while the light colored minerals predominate, the dark minerals of biotite, hornblende, and augite are almost always prominate. In conection with these there may be minor components of plagioclase, aegirite, augite, magnetite, titanite, zircon, and apatite. The texture is granitiod. If we take from this type quartz, we have a granitè; if the texture be altered a trachyte results. In the case where biotite occurs, a rock known as a mica-syenite is produced. Augite-syenites and leucite-syenites are so named because of the predominating mineral being one of these. Associated with biotite and hornblende as essential minerals, may be small quanities of plagioclase. In such a case the rock becomes a monzonite. From this it is seen that the monzonite group is a transition from the syenites to the diorites. It is to be noted that as a rule the feldspar in an igneous rock is the most important constituent. There are however exceptions to this case. Sometimes augite may become so prominent as to exceed the orthoclase feldspar; in this instance a shonkinite is the rock formed.

Phonolites and Related Groups.--Phonolites present a texture ranging from felsitic to porphyritic. Comprising the principle part of the rock are the minerals of nephelite, biotite, augite, and hornblende. With these are associated small quanities of plagioclase, leucite, sodalite, tourmaline and spinel. Silica percentage ranges from sixty nine and ninety six hundredths percent to sixty five and sixty eight hundreths; alumina from seventeen fifty five to fourteen fifty seven; ferric oxide from two to three; sodium oxide from three to five; potassium oxide from five to seven; magnesium oxide from five tenths to one; calcium oxide from one to two. When any special mineral constitutes the largest part of the rock the name is denoted by this characteristic mineral; for example, if sodalite predominates the rock is a sodalite-phonalite

Nephelite Syenites and Related Groups.--The essential minerals of this group are the same as those of the phonolites.

This rock type represents coarsely porphyritic varities of phonolites. Indeed, the texture may become granitiod and in such a case we have a typical nephelite syenites. It differs from rhyolite in texture and its absence of quartz; from granites in the quartz by nephelite; and from syenites by the presence of nephelite.

Dacites and Related Groups.--Dacites are the first of a very important group of rocks the essential minerals of which are dark colored. This property gives an excellent basis upon which to distinguish the plagioclase and the orthoclase varieties of igneous rocks. It has been noted that in all previous types, those minerals which give character to the rock are light colored, and also that the chief feldspar is orthoclase. Now we shall consider those rocks in which plagioclase is the important feldspar. The essential minerals in the dacites are quartz, biotite, hornblende, augite and plagioclase, while the accessory components are usually titanite, zircon, apatite and the iron ores. Representing as it does, the first type in this division texture ranges from felsitic to porphyritic. Quartz-pantellerites are those rocks in which the plagioclase of the dacites have been replased by anorthoclase; it is thus related to rhyolites.

Quartz-Diorites and Related Groups.--In quartz-diorites the texture ranges from coarsely porphyritic to granitoid. Although the essential minerals are the same as those of the dacites, the distinction lies in texture. If quartz be replaced by nephelite we have a nephelite-syenite. The relation between the granites and quartz diorites lies wholly in the feldspar, the former containin orthoclase the latter plagioclase as chief feldspar.

Andesites and Related Groups.--Andesites are generally red or brown in color possessing besides plagioclase, hornblende, biotite, and augite as essential minerals. A felsitic texture surrounding more less well defined phenocrysts, is the fabric generally presented. Their relation to the quartz-diorites consists in a change of texture; to the dacites in the presence of quartz in the latter. Difficulty may arise in distinguishing this group (the andesites) from the trachytes. The difference is evidently not one of texture but one of mineral content, the former containing a plagioclase and the latter containing orthoclase as the chief feldspar.

Diorites and Related Groups.--Passing from the andesites with the porphyritic texture to the diorites, we encounter rocks the texture of which range from coarsely porphyritic to granitoid. the most closely related group is the quartz diorites which contain free quartz as a distinguishing feature.

Basalts and Related Groups.--These are extremely dark and dence rocks of porphyritic texture, containing plagioclase as the chief feldspar and olivine, hornblende, serpentine, and pyroxene as the essential minerals. The silica percentage is unusually low ranging from fifty to fifty five percent while the lime as would be expected runs very high, from seven to nine percent.

Gabbros and Related Groups.--In the types previously considered hornblende and biotite come in very strong. However when the gabbros are reached the pyroxenes become very prominent as is seen from the high range of lime from six to seven. This lime content is contributed not only by the pyroxenes but also by the calcium aluminium silicate-anorthite. Texture is usually granitoid. If in connection with pyroxene there may be hornblende in which case we have a gabbro-diorite.

Conclusion.

Reference has been made to the position held by the Rocky Mountain belt in the petrographical series. While the investigation which led to the assignment of this position, has been the result of careful field work, it must be understood that every igneous body in this province has not as yet been examined. There may be a great number yet unknown, the discovery of which will either add to or detract from the present opinion regarding the rock type in this region. However it is the belief of the writer that the igneous bodies include by far the great majority in actual existence, and that the few isolated formations which still remain unnoted, constitu such a small portion of the whole as to be almost insignificant.

The great country lying East of the Pacific Coast as far inland as Montana is said to belong to the acidic type this is to those rocks rich in silica. In Utah the chief feldspars are orthoclase, sanadine, anorthoclase and microcline; the feldspathoids nephelite, sodalite and leucite. Glasses here are very common and are represented in the Iron County obsidian, the Millard County scoria and the basaltic flows at the northern part of Utah. Rhyolites are very numerous and occur chiefly as dykes and in connection with other igneous intrusions. The Rhyolites of Bingham, Tintic, Ophir and Little Cottonwood Canyon, are the important formations. The Granites represent by far the most important igneous rocks of Utah. The great intrusions of the Wasatch Range stand out as head-liners in the petrographical column. Trachytes too are common but less so than the granites. Beaver, Wasatch, Eureka, Traverse Mountains, Park City and Bingham contribute the Trachyte type. Syenites are very scarce, one being known in Millard County.

Typical Phonolites and Nephelite Syenites are unknown. The Dacite group, which is rich in the plagioclase minerals and containing quartz is wanting. Quartz Diorites are rare. Andesites are well represented, in Eureka, Traverse Mountains, Ophir, Wasatch County, Park City and the Uinta Range. Diorites are not few in number. Basalts are represented in the flows at Northern Utah and Gabbros are not found within the province.

Plate I.

Fig. 1.

Fig. 2.

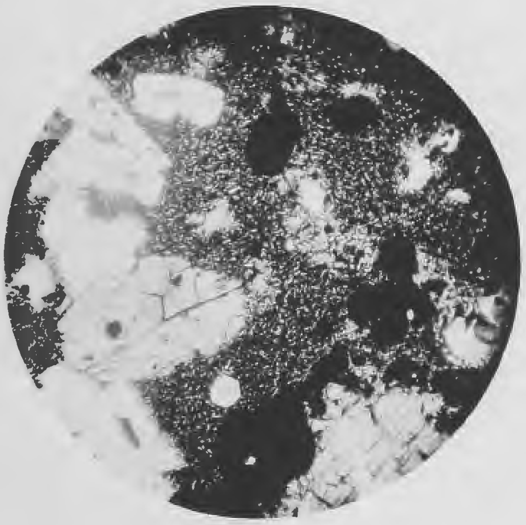


Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Plate 11.

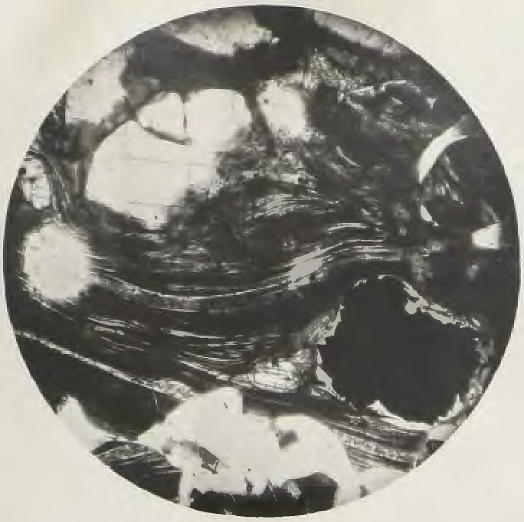


Fig. 1.

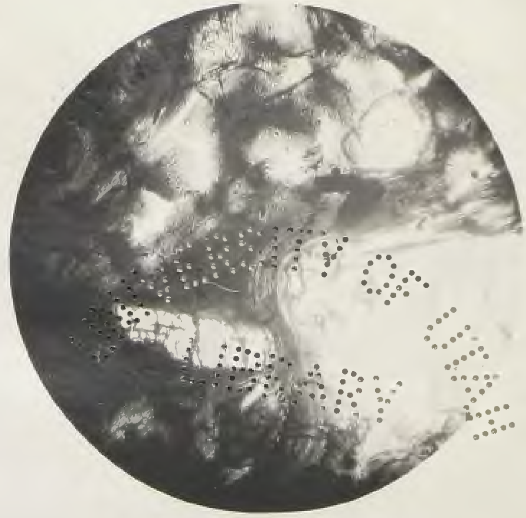


Fig. 2.

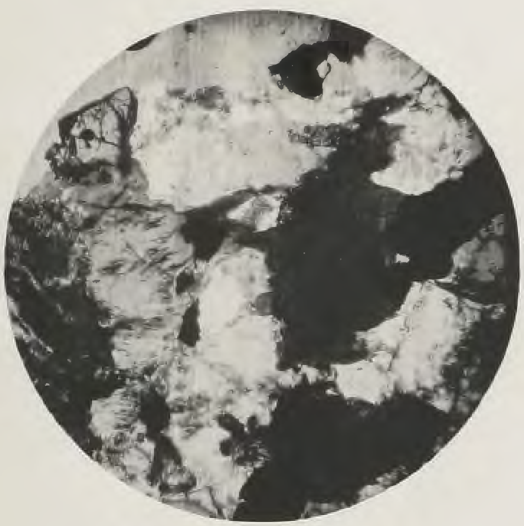


Fig. 3.

Fig. 4.

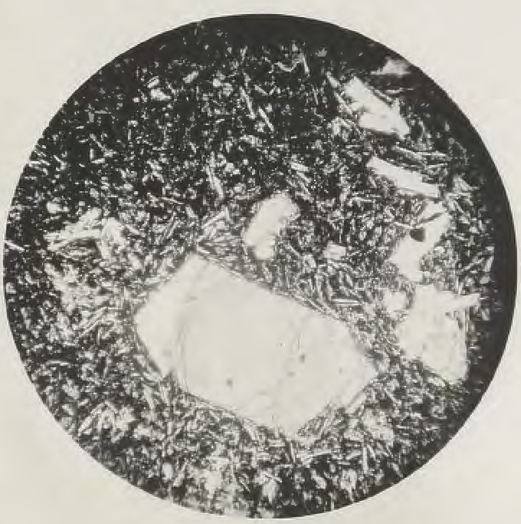


Fig. 5.

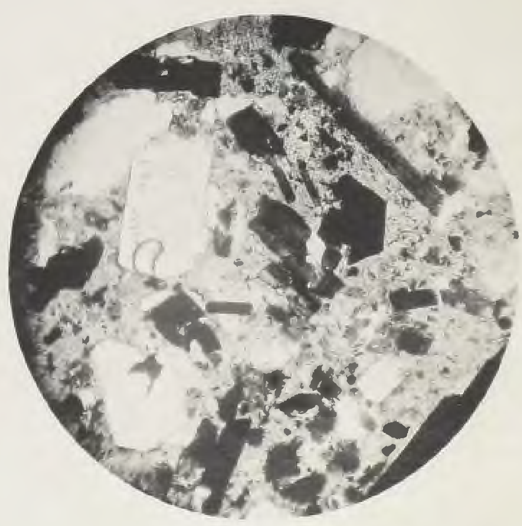


Fig. 6.

Plate III.

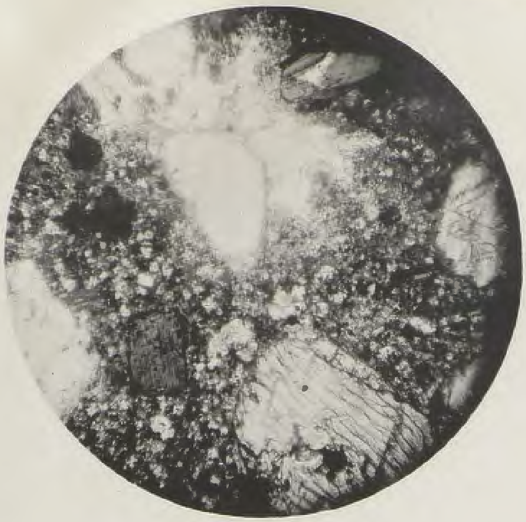


Fig. 1.

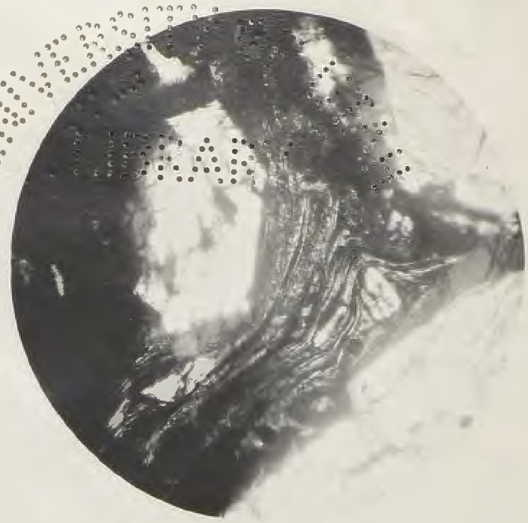


Fig. 2.

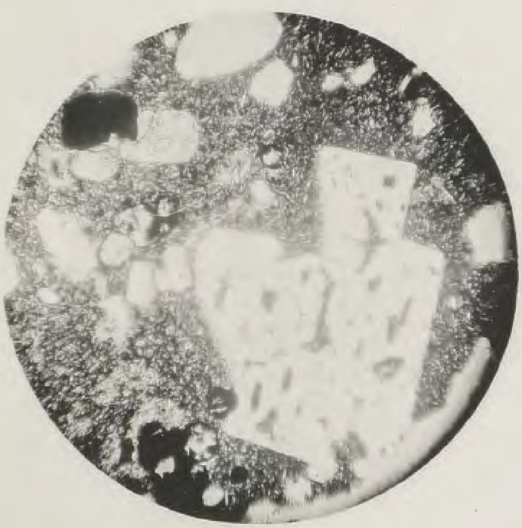
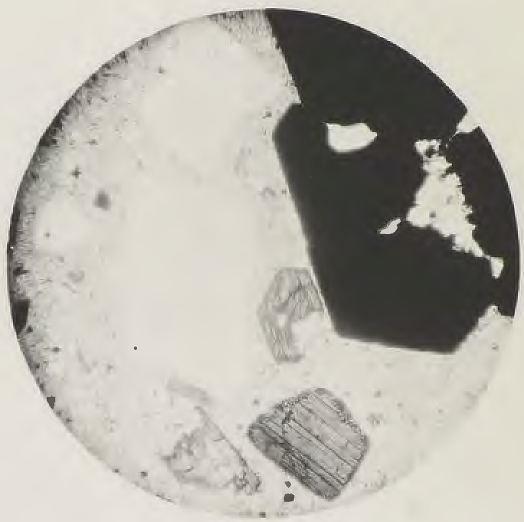


Fig. 3.



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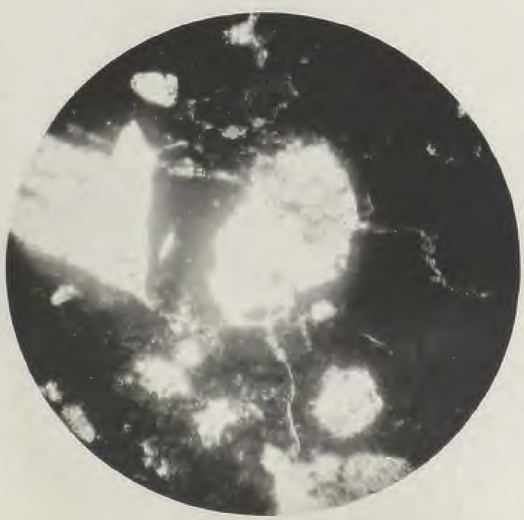

Fig. 5.

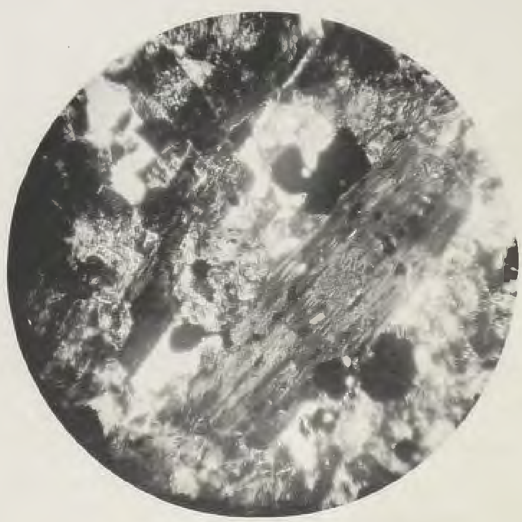

Fig. 6.

Plate IV.

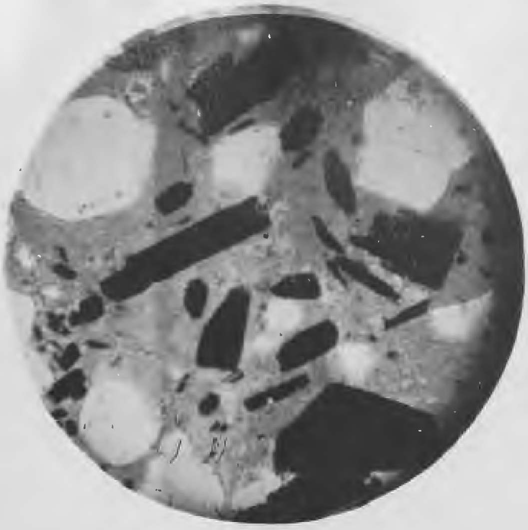

Fig. 1.

Fig. 2.

Fig. 3.

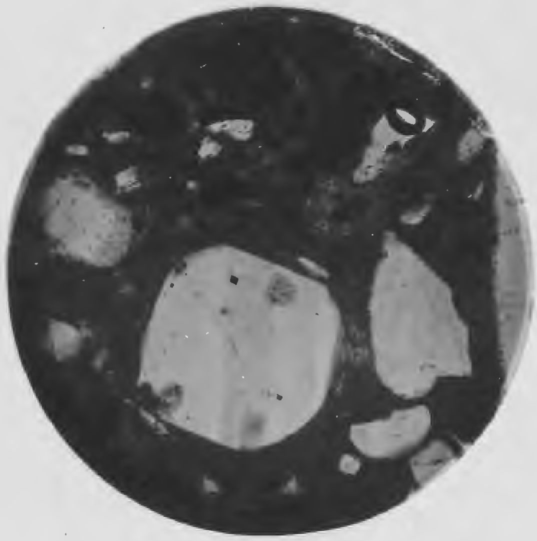

Fig. 4.

Fig. 5.

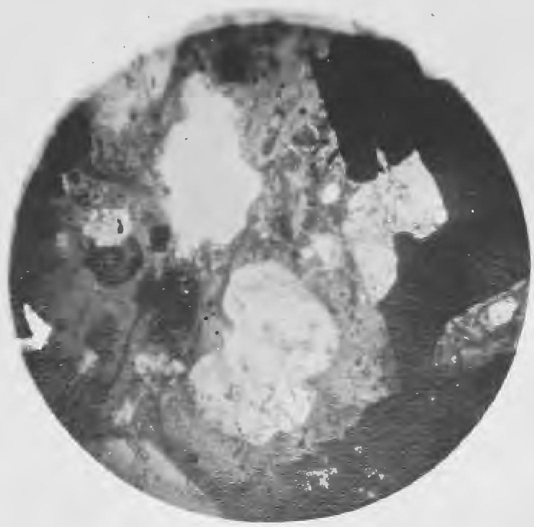

Fig. 6.

Plate V.

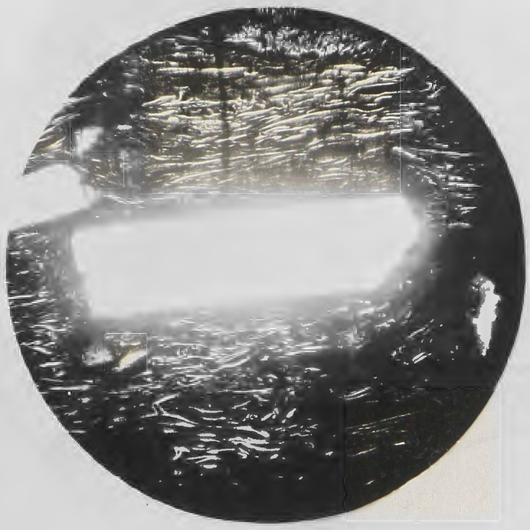

Fig. 1.

Fig. 2.

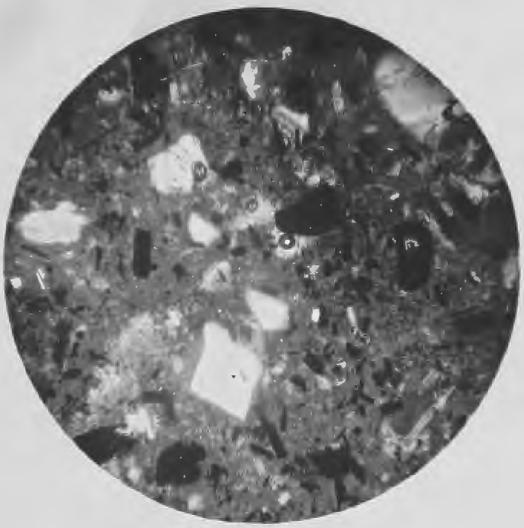

Fig. 3.

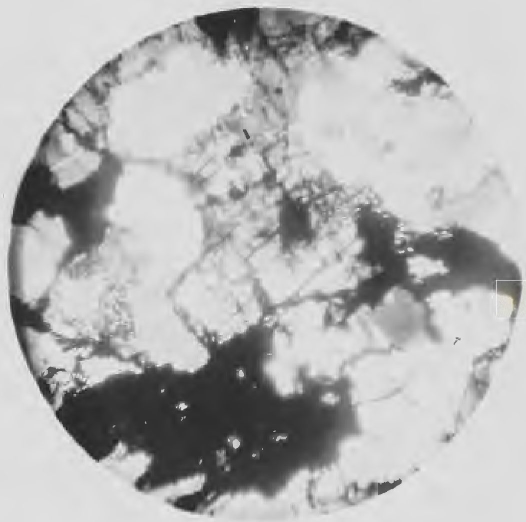

Fig. 4.

Fig. 5.

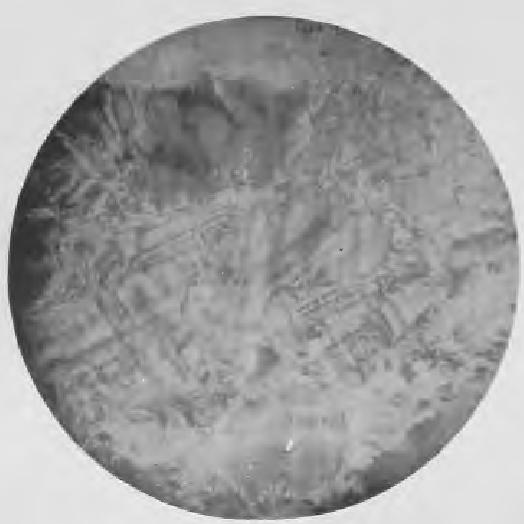

Fig. 6.

Plate VI.

Fig. 1.

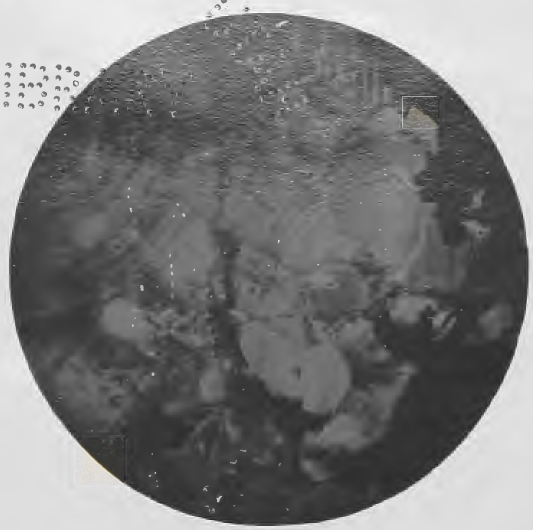

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Plate VII.

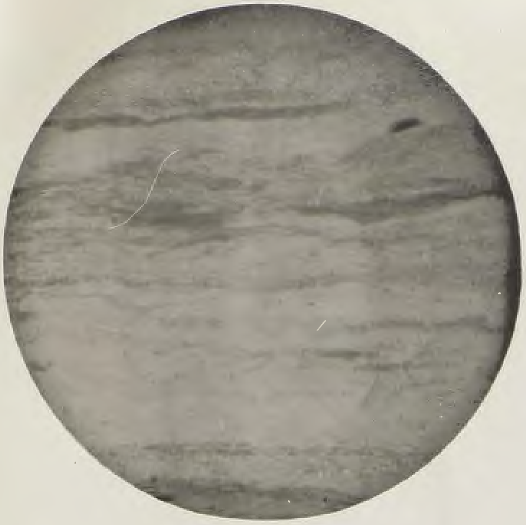

Fig. 1.

Fig. 2.

Fig. 3.

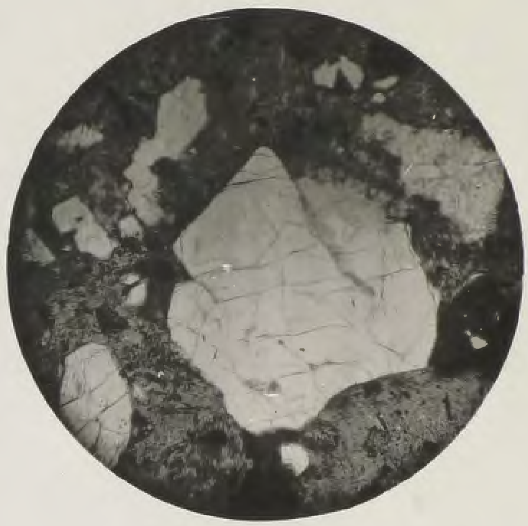

Fig. 4.

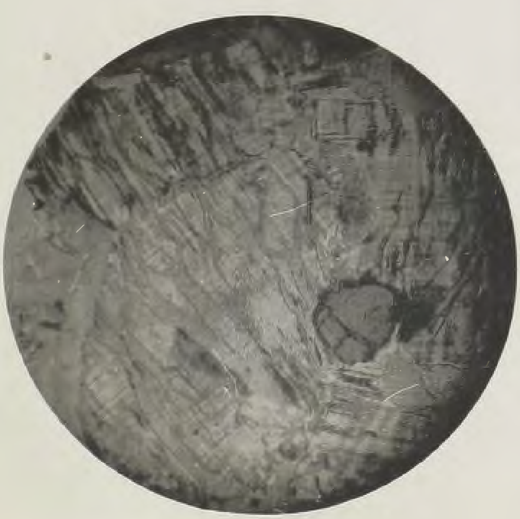

Fig. 5.

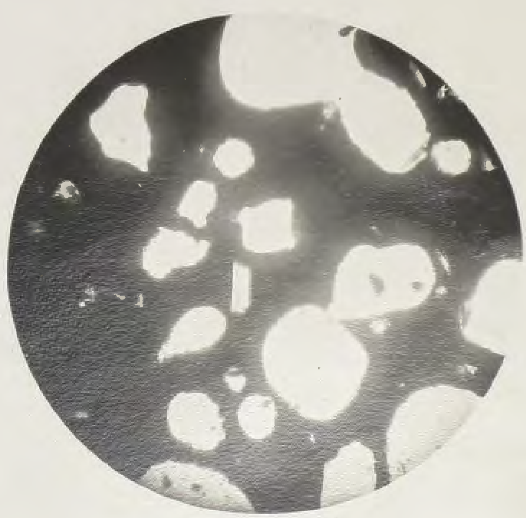

Fig.