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GEOLOGY AND PETROGRAPHY OF THE CAMPUS ANDESITE PLUTON, EL PASO COUNTY, TEXAS

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ABSTRACT

The Campus Andesite represents a small pluton that crops out on the campus of the University of Texas at El Paso in the Rio Grande valley. The igneous mass is post-Cretaceous in age showing intrusive contacts with shale and marl of the Boquillas Formation and is surrounded by Quaternary lake and alluvial deposits.

Texturally, the intrusive is porphyritic with phenocrysts averaging 2-3 mm in length and set in an aphanitic groundmass. The phenocrysts, composed predominantly of plagioclase (andesine), comprise approximately 40% of the rock. The mineralogy of the andesite consists of phenocrysts of plagioclase, biotite, and hornblende with groundmass constituents of plagioclase, K-feldspar, and minor quartz and magnetite.

Two chemical analyses of Campus Andesite indicate a chemical composition intermediate between an andesite and a dacite. Mineralogically, the rock is classified as a porphyritic andesite.

RESUMEN

La Andesita Campus es un pequeflo cuerpo plutónico situado en el valle del Rio Grande y aflora en los terrenos de la Universidad de Texas en El Paso. La masa ignea es de edad postcretácica y muestra contactor intrusivos con lutita y marga de la Formación Boquillas. Está rodeado por depósitos aluviales y lacustres cauternarios. La textura del intrusivo es porfidica con fenocristales cuyo largo en promedio es de 2-3 mm los cuales están en una matriz afanitica. Los fenocristales, compuestos predominantementc de plagioclasa (andesina), comprenden aproximadamente el 40% de la roca. La mineralogia de la andesita consiste de fenocristales de plagioclasa, biotita y hornblenda con matriz constituida de plagioclasa, feldespato potásico y una parte menor de cuarzo y magnetita.

Dos anAlisis quimicos de la Andesita de Campus, indican una composición quimica intermedia entre una andesita y una dacita. Mineralógicamente, la roca está clasificada como una andesita porfidica.

INTRODUCTION AND GEOLOGIC SETTING

A series of small andesitic plutons crop out in the Rio Grande valley in extreme west Texas near the city of El Paso, El Paso County, Texas (see fig. 1). The only published information concerning these intrusives consists of preliminary description and mapping by Richardson in the El Paso Folio (1909). A mass of related intrusive porphyry, termed Cerro de Muleros (Sierra de Cristo Rey) and located a short distance west of El Paso, astride the international boundary between the United States and Mexico, has been mapped and described by Bose, 1910, Sayre and Livingston, 1945, and Strain, 1968b.

These intrusives trend north-northwest in the Mesilla Bolson. They are bounded on the east by the westward dipping strata of the Franklin Mountains and on the west by the La Mesa escarpment. The plutons range from less than one-eighth to over two square miles in area, and are either completely surrounded by Quaternary lake and alluvial deposits or show intrusive contacts with Cretaceous strata (Richardson, 1909) . The porphyry bodies on the basis of similar composition and intrusive relations with Cretaceous strata, are thought to be late Cretaceous or Tertiary in age; they were emplaced during the period of deformation that produced the uplift and faulting in the Franklin Moun-

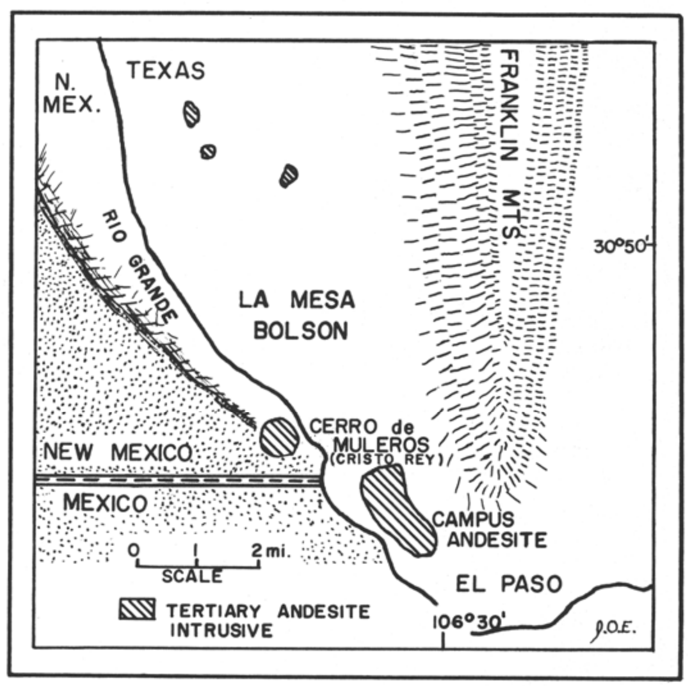

FIGURE 1.
Index map of the Campus Andesite.

tains and formation of the intervening basins (Richardson, 1909).

The largest of these intrusive bodies is herein designated as the Campus Andesite because it crops out on the campus of the University of Texas at El Paso. This pluton crops out over an area of approximately two square miles; it is almost entirely bounded on the east by Mesa Street, on the south by Main Street, and on the west by the Rio Grande (see fig. 2).

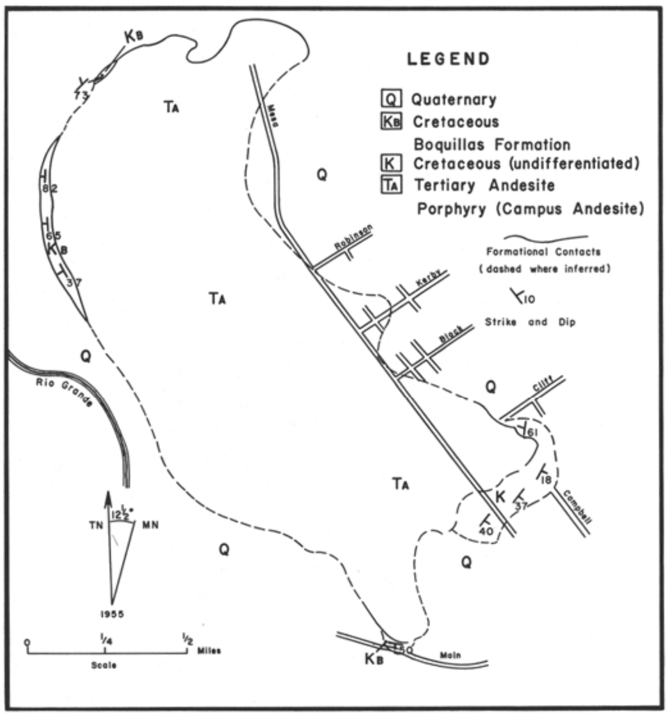

FIGURE 2.
Geologic map of the Campus Andesite.

The Cerro de Muleros (Sierra de Cristo Rey) intrusive mass, located one mile west of the Campus Andesite on the west side of the Rio Grande, has been described as a laccolithic-type mountain with an andesite porphyry core flanked by steeply dipping, and locally highly faulted and folded Cretaceous strata (Richardson, 1909, Bose, 1910, and Strain, 1968b). However, the laccolithic structure of Cristo Rey has not been definitely established as nowhere is the base of the porphyry exposed. Therefore, the intrusion should presently be described as a pluton.

PHYSICAL ASPECTS OF THE CAMPUS ANDESITE

FORM AND APPEARANCE

The Campus Andesite forms a series of small hills with maximum relief of approximately 250 feet. The outcrops support only sparse vegetation, principally creosote bush, yucca, ocotillo, and lechuquilla (Johnson, 1968). The ex posed part of the intrusive body is elongate, a little over one mile wide and approximately two miles long; the trend of the porphyry mass is north-northwest.

The intrusive is traversed by many well-developed joint sets and is highly weathered. The degree of weathering is most intense near the sedimentary-igneous contacts and in other areas where the joints are closely spaced. In highly weathered areas, the rock has a granular appearance and spheroidal weathering is well-developed. Weathering of biotite and hornblende causes a yellow-brown iron-oxide coloration on the surface. More intense or prolonged weathering has attacked the plagioclase phenocrysts, producing clays and some replacement by calcite; such outcrops are light to dark gray in color. On moderately fresh outcrops the rock is distinctly porphyritic with phenocrysts of light-gray plagioclase and black to dark-brown biotite and hornblende, up to 5 mm, set in a fine-grained dull-gray groundmass.

CONTACT FEATURES

The intrusive is surrounded predominantly by late Cenozoic strata of lacustrine and fluvial origin (Strain, 1968a). These beds, consisting of claystone, siltstone, sand, and gravel of the Fort Hancock and Camp Rice Formations, are best developed on the northeast, north, and southwest margins of the igneous mass, covering the intrusive contact in these areas (Strain, 1968a) .

There are four areas where the Campus Andesite can be seen in intrusive contact with shale, marl, and limestone of Cretaceous age (see fig. 2). On the west side of the igneous mass, near the Rio Grande, thin-bedded Cretaceous shale of the Boquillas Formation crops out over an area approximately 4,000 feet in length and 50 feet wide, in sharp contact with the andesite porphyry. The intruded shale strikes approximately N 20° W, with dips averaging about 70° westward. In local areas the shale beds stand perpendicular or are slightly overturned. Contact effects in the shale consist principally of minor silicification and baking.

On the northwest margin of the intrusion a small outcrop of thinly bedded shale and marl of the Boquillas Formation occur in sharp contact with the intrusive. These beds strike N 50° E and dip away from the intrusive at approximately 75°. A few hundred feet away from the contact zone the dip of the shales ranges from 30° to 40°, but near the contact it reaches a maximum of about 80°. Also, as the contact is approached the degree of compaction and silification of the shale is greater and the color is darker. Numerous small veins of calcite and joints are present in the shales within about 500 feet of the contact.

At the south end of the intrusion, just north of Main Street in roadcuts along Interstate 10, there are several small outcrops of Boquillas shale. The shale strikes from N 80° W to N 40° E at the south end of the intrusion and dips from 43° to 65° toward the south. Near the intrusion the shale is silicified and is dark-gray to green but the degree of silicification is less away from the contact zone toward the east as the shale disappears beneath younger late Quaternary river gravel and sand.

Small scattered outcrops of Cretaceous limestone occur at or near the igneous contact on the southeast margin of the andesite in the vicinity of Nevada and Cliff streets. The limestone is light brown to yellow in color, slightly silicified, and strikes generally northeast (N 5° E to N 69° E) . The dips are generally away from the intrusion, averaging about 35° toward the southeast. However, locally (in an alley near Florence and River streets) the limestone dips steeply into the intrusion or stands vertical in direct contact with the intrusion. Because of the degree of alteration and lack of fossils in the limestone, a definite formational name has not been assigned to this unit (Strain, personal communication). Contact metamorphic effects in the Cretaceous rocks surrounding the Campus Andesite are not well-developed; only minor silicification and baking have been observed.

The sharp sedimentary-igneous contacts, steep dips of contact sedimentary rocks, and minor silicification in the Cretaceous rocks definitely establish the intrusive nature of the Campus Andesite. However, because of the limited vertical exposure of the outcrops the conformable or nonconformable extent of contact zones at depth cannot be established. Therefore, the intrusion is best described as a small igneous pluton. In addition, the exact relationship between the Campus Andesite and the other andesitic intrusions, notably the Cristo Rey intrusion, located only a short distance to the west, cannot be established at this time. Either each individual andesite outcrop represents a separate intrusive or the intrusive outcrops represent exposed apophyses of one or more larger igneous bodies at depth.

XENOLITHS

Inclusions of shale, limestone, quartz sandstone, and subangular masses of hornblende, hornblende-mica, and hornblende-biotite-feldspar occur in the Campus Andesite. Generally, the inclusions are small, averaging about two inches, and are usually wedge-shaped. They seem to be most abundant near the contact zones where, at places, they display orientations parallel to the contact. Inclusions of limestone, shale, and quartz sandstone most likely represent fragments of the surrounding Cretaceous strata that were incorporated in the andesite magma during emplacement.

The origin of the predominantly hornblende fragments does not seem to be so simple. At least three possibilities can be suggested to account for their presence. First, they may represent segregations of hornblende and/or mica and feldspar that separated from the magma during early crystallization. Second, they could be the result of reorganization and recrystallization of shale minerals resulting from reaction with magma. At Cristo Rey, hornblende inclusions appear to be more abundant in the pluton where some of the hornblende fragments show gradation into shale near the contact zones. Third, these hornblende masses might represent fragments of basement rock brought up from depth by the intrusion. On the basis of a preliminary study of the hornblende fragments, the writer believes that at least some of the masses were formed by reaction of shale with the magma.

PETROGRAPHY OF THE CAMPUS ANDESITE

INTRODUCTION

Approximately fifty samples of Campus Andesite were collected during mapping of the intrusive and the surrounding sedimentary rocks. From these samples, forty were selected for the preparation of standard thin-sections and were analyzed mineralogically and texturally with the petrographic microscope. Mineral percentages were determined by point counting with a Bausch and Lomb microprojector on a grid-ruled base.

TEXTURE

The Campus pluton is a fine-grained, light-colored, porphyritic rock of andesitic composition. All samples studied are holocrystalline and porphyritic with phenocrysts ranging from 30 to 55 per cent of the rock and averaging approximately 40 per cent. The phenocrysts average 2-3 mm in diameter and are composed predominantly of subhedral to euhedral plagioclase feldspars with subordinate amounts of subhedral biotite and hornblende.

Glomeroporphyritic development among the plagioclase phenocrysts is well-developed in many areas of the intrusion with parallel to subparallel development of the mafic minerals around the plagioclase phenocrysts. Near the margins of the intrusion the elongate phenocrysts of feldspar, biotite, and hornblende show parallel to subparallel orientation with the contact, developed during flowage of the magma at the time of emplacement.

The fine-grained groundmass is composed essentially of subhedral to anhedral plagioclase, with minor quantities of anhedral potash feldspar and quartz. Because the individual groundmass crystals are so small, averaging about 0.05 mm in diameter, positive identification is very difficult in the thin sections. Therefore, 10-15 rock slabs and thin sections were stained with potassium rhodizonate and cobaltinitrate solutions to detect the presence of plagioclase and potash-feldspar, respectively (Bailey and Stevens, 1960) . The results indicate that approximately 80 per cent of groundmass is composed of plagioclase with subordinate amounts of potash feldspar and quartz.

MINERALOGY OF THE CAMPUS ANDESITE

INTRODUCTION

The Campus Andesite consists predominantly of plagioclase feldspar with subordinate amounts of biotite, hornblende, quartz, magnetite, potash feldspar, with minor amounts of apatite and zircon. Alteration products, which are abundant locally, consist of clay, sericite, iron oxide, and calcite.

ESSENTIAL MINERALS

Plagioclase feldspar occurs abundantly as both phenocryst and groundmass crystals and averages about seventy-five percent of the andesite. The phenocryst plagioclase is euhedral to subhedral and averages 1 to 2 mm in size, whereas the groundmass plagioclases average only 0.05 mm and are subhedral.

Zoning is widespread in the plagioclase phenocrysts with normal, oscillatory, and reverse types present in that order of abundance. In general, most phenocryst plagioclases possess highest An content in the cores, ranging from An_{33} to An_{48} and averaging approximately An_{40} (andesine). The exterior regions of the zoned crystals are usually lowest in An content, ranging from An_{a}, to An_{38} and averaging about An_{28} (calcic oligoclase). Most of the compositional zones show moderately sharp boundaries. However, in a few crystals the core zones are very irregular in shape and show highly gradational boundaries. In addition, "patchy" or "irregular islands" of extinction in the core regions of some crystals probably represent partial replacement of compositionally different plagioclase during reaction of the early formed crystal with the magma. Oscillatory zoning is quite common with the presence of four to five alternations in the composition from the edge to the core of the crystal.

Twinning is widespread among the plagioclase phenocrysts with the albite-type most abundant. Combined albite-carlsbad and albite-carlsbad-pericline twins are also present.

Many of the phenocryst feldspar show numerous irregular fractures and display a moderate tendency to glomeroporphyritic development. In some cases as many as 5 or 6 plagioclase crystals occur intergrown in a mass 2 to 4 mm in diameter and as crystal clusters with no visible intergrowth.

Alteration of the phenocryst plagioclase has produced sericite, kaolinite, and calcite. The degree of alteration is not uniform. In general, alteration is greatest near the contact with the sedimentary rock and, as expected, most intense in samples located nearest the joint surfaces. In some samples, weathering alteration has been so intense that the twin lamellae have been completely destroyed and the crystal almost completely replaced by kaolinite and/or calcite, particularly near the southern edge of the intrusion where alteration has been most intense. In samples less intensely weathered, the alteration is preferential with the more calcic zones of the plagioclases showing alteration to clay but the more sodic exteriors remaining unaltered.

VARIETAL MINERALS

Biotite and hornblende occur almost exclusively as phenocrysts, ranging in size from 0.5 mm to 3.0 mm and averaging about 1.0 mm. These mafic minerals range from 4 to 12 per cent of the andesite and average approximately 9 per cent. They seem to be most abundant near the margins of the intrusion.

Biotite, generally twice as abundant as hornblende, occurs in elongate subhedral to euhedral crystals with some inclusions of apatite, zircon, and magnetite. Typically, the biotite crystals display jagged and irregular outlines rimmed by small magnetite crystals formed by reaction with the magma. Also common is the parallel to subparallel arrangement of biotite either around plagioclase phenocrysts or in the ground-mass, representing flow structure that developed before complete solidification of the magma. Where biotite is found in contact with hornblende, it appears to replace the hornblende.

The degree of alteration of biotite ranges from high to low. Generally, in the interior parts of the intrusion the biotite appears to be less altered and is a deeply pleochroic brown with subhedral to euhedral outline and some alteration to chlorite-like materials. However, on or near the margins of the intrusion the biotite appears highly altered and more anhedral in shape with the pleochroism masked by alteration to iron oxides and clay. In some cases only the crystal outline remains, having been completely replaced by secondary calcite and iron oxide.

Hornblende, averaging approximately four percent of the andesite, occurs predominantly as subhedral to euhedral phenocrysts displaying various shades of green and brown with marked pleochroism. Some crystals show color zonation and extinction with green borders and brown patchy interiors. Also observed are euhedral twinned and zoned hornblende crystals.

Some evidence exists to suggest the possibility of two periods of hornblende growth. The predominantly brown pleochroic hornblende shows evidence of replacement by biotite. On the other hand, the green pleochroic varieties contain inclusions of biotite which indicate formation after initial biotite crystalization. The difference in color between the brown and green hornblende has been attributed to higher Si02, lower Al_20_3, lower Na_t + K_2O, and lower TiO_2 in the green variety compared to the brown (Heinrich, 1965) .

Typically, the hornblende shows alteration ranging from almost complete replacement by iron oxides and/or calcite to minor alterations of chlorite and iron oxides. Numerous hornblende crystals show resorption or reaction effects and are partly replaced along the margins by fine-grained augite (?) and finely disseminated magnetite. As in the case of biotite, subparallel to parallel alignment of prismatic hornblende crystals is common around plagioclase phenocrysts.

ACCESSORY MINERALS

Quartz and potash feldspar, averaging three and ten per cent respectively, occur as anhedral groundmass crystals. They average approximately 0.05 mm in size, but in places there are large subhedral quartz crystals, up to 2 mm in diameter.

Not all the quartz in the andesite is of primary origin. In many samples there are small fragments or masses of well-rounded quartz grains and mixtures of chlorite, epidote, calcite, and iron oxides. The quartz crystals in these masses show irregular and gradational outer boundaries, but within the fragments the boundaries are well rounded and sharp. These fragments (up to 3 mm) undoubtedly represent small xenoliths of quartz-rich Cretaceous rocks partially digested by the magma. The primary quartz can be differentiated from the included quartz because of its anhedral shape, smaller size, and individual occurrence throughout the groundmass.

Magnetite, zircon, and apatite occur as subhedral to euhedral crystal inclusions within the more abundant minerals, notably biotite and hornblende. In addition, magnetite, averaging approximately two percent of the andesite, occurs as small disseminated crystals around mafic crystals and as larger subhedral crystals, up to 1.0 mm in diameter scattered throughout the groundmass. Zircon and apatite occur in some places as individual euhedral crystals in the groundmass.

MINERAL VARIATIONS

The texture and mineralogy of the Campus Andesite appear to be rather homogeneous throughout the exposed area of the intrusion, except for the distribution of the mafic minerals. The mafics, biotite and hornblende, range from 4 to 12 per cent of the andesite. Figure 3 shows the percentage of mafics for each andesite sample plotted against the distance of the sample, in feet, from the nearest edge of the intrusion. Although the correlation is not perfect, it indicates that samples containing the greater percentages of mafics are located, generally, nearest to the edge of the intrusion.

The mafic-rich border is thought to be the result of reaction between the andesite magma and the predominantly argillaceous country rock, whereby the minerals of the latter have been converted to those crystalline phases (predominantly hornblende and biotite) with which the liquid phase of the magma was in equilibrium at the time of intrusion (Turner and Verhoogen, 1960) . This process of assimilative reaction, suggested by Bowen (1928), could also explain the origin of the hornblende, hornblende-biotite, and hornblende-biotite-feldspar xenoliths that are found in the intrusive. The exact mechanism by which the ions involved are exchanged between the xenoliths and magma is not clearly understood (Turner and Verhoogen, 1960). Nockolds (1933) has suggested that the necessary ionic exchange is effected through the medium of a mobile aqueous fluid which is assumed to separate from the magma and penetrate the xenolith.

CHEMICAL COMPOSITION OF THE CAMPUS ANDESITE

Two samples of the andesite pluton were selected for chemical analysis; one from the central part of the igneous mass and one from the border zone. The results of the analyses, along with the calculated normative minerals and average mode of the andesite, are given in Table I.

One of the chracteristic features of the andesite is the high alkali content: Na_20 and K_2O average 6.0 and 2.8 per cent respectively. The high alkali content is expressed in the normative calculations by an average of approximately 17 percent orthoclase and 55 percent albite.

Both analyses are similar except that the border sample shows higher amounts of Fe, Mg, and Na oxides and lower quantities of Si, Al, Ca, and K oxides than the sample from the interior of the pluton. These differences are expressed in the normative calculations by a greater abundance of diopside-hypersthene (6.0 vs. 7.1 percent) in the border andesite and corresponding lower values of feldspar and quartz (see Table I). In addition, the border enrichment

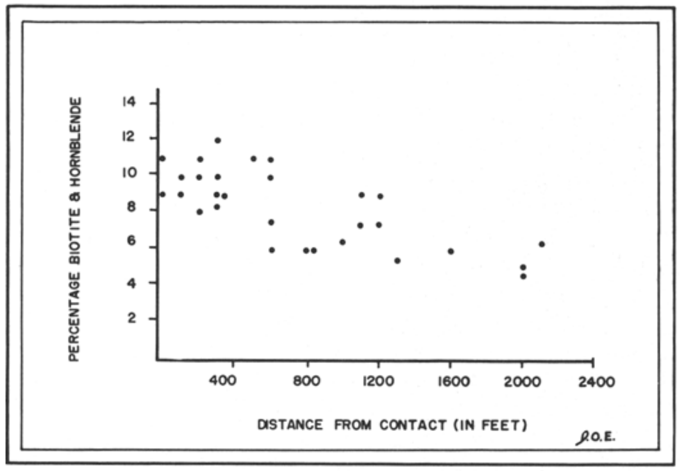

FIGURE 3.
Total mafics (Hornblende + biotite) plotted versus distance from nearest contact in the Campus Andesite.

of mafics is further substantiated by the fact that modal mafics are more abundant in the border zone (see fig. 3).

The relatively high combined water content of the two samples (3.25 and 2.42 percent) is probably due to the occurrence of biotite and hornblende and the presence of alteration derived clays.

Based on the chemical analyses, the Campus pluton is intermediate in classification between a dacite and an andesite. The total silica, averaging 62.0 percent, more closely approximates that of the average dacite (63.6 percent) than the average andesite (54.2 percent) (Nockolds, 1954). However, the presence of secondary quartz, from quartz-rich xenoliths, would cause a higher total silica content in the analysis. In addition, notably lower values of Fe^{+2}, Fe^{+3}, Mg, and Ca oxides and higher amounts of Na and K oxides and combined water occur in the Campus Andesite relative to the average andesite and dacite. The explanation for some of these differences is probably the result of the moderate to high degree of weathering in the andesite. Minerals which contain Fe, Mg, and Ca, such as biotite, hornblende, and calcium plagioclase have been generally altered whereas the minerals rich in K and Na such as orthoclase and sodic plagioclase are less altered.

PETROLOGY OF THE CAMPUS ANDESITE

Plagioclase feldspar, magnetite, zircon, and apatite were the first minerals to crystallize from the andesitic magma at depth. Owing to some reaction that prevented the plagioclase crystals from maintaining equilibrium with the magmatic melt, zoning developed in these crystals. Generally, the zones grade outward from a more calcic core of andesine to a more sodic border of calcic oligoclase, but reverse and oscillatory zoning are also common.

After the initial formation of the plagioclase phenocrysts, mafic minerals began to crystallize from the magma, first hornblende and then biotite. Mafic crystallization probably was nearly contemporaneous with movement of andesite

TABLE I

CHEMICAL OXIDES			NORMATIVE MINERALS*			MODAL MINERALS	
	(1)	(2)		(1)	(2)	Ap	1.0%
SiO_2	61.63%	62.52%	Ap	1.060%	0.974%	Mg + Il	2.0%
Al_2O_3	16.71%	17.42%	Il	0.593%	0.584%	Or	10.0%
Fe_2O_3	1.52%	1.44%	Or	17.272%	17.571%	Ab + An	75.0%
FeO	1.57%	1.45%	Ab	53.069%	51.705%	Hrn	4.0%
MnO	0.23%	0.29%	An	10.640%	12.525%	Bio	5.0%
MgO	1.41%	1.29%	Mg	2.292%	2.141%		
CaO	3.49%	3.55%	Di	3.557%	2.274%		
Na_2O	6.03%	5.96%	Hy	3.557%	3.749%		
K_2O	2.81%	2.90%	Q	7.960%	8.478%	Q	3.0%
TiO_2	0.30%	0.30%		100.000%	100.000%		100.0%
P_2O_2	0.44%	0.41%					
$H_2O\pm$	3.25%	2.42%					
	99.39%	99.94%					

Chemical and Mineral Data of the Campus Andesite (sample #1 is from the southwest margin of the intrusion and sample #2 is from the center of the intrusion at the base of the seismograph station, The University of Texas at El Paso.) *CIPW Classification system by Charles Ondrick and John Holloway (1967), Penn State University and modified by D. V. LeMone and M. Adams for CDC 3100B (1969), University of Texas at El Paso; program deposited at Computations Center, U. T. El Paso.

magma toward the surface. During intrusion the overlying Cretaceous strata were arched upward. Fragments of the Cretaceous rocks fell into the magma and are present today as inclusions of shale, limestone, and quartz sandstone. In some areas, notably along the margins of the andesite, assimilative reactions converted the predominantly argillaceous country rock into hornblende and biotite, thereby accounting for the mafic-rich border. Complete assimilation of isolated argillaceous fragments accounts for the presence of the dominantly hornblende-biotite xenoliths. The large size, subhedral to euhedral crystal form, and the development of flow structure of the mafics indicate their formation before the magma reached its present position in the crust where it encountered an environment of more rapid cooling. Magnetite rims around many of the hornblende and biotite crystals indicate reaction between these crystals and the magma and, therefore, conditions of disequilibrium.

The fine-grained groundmass indicates that the magma probably was intruded to a shallow depth beneath the surface and then cooled very quickly. The late minerals to crystallize in the magna were crystals of anhedral plagioclase, potash feldspar, and quartz. Obscureness of contact metamorphism in the surrounding sediments probably was due to the rapid cooling of the intrusion after emplacement.

Since emplacement of the andesite porphyry, erosion has stripped away the overlying sedimentary strata and exposed the igneous rock. Subsequent weathering of the andesite attacked phenocrysts of plagioclase, biotite, and hornblende producing sericite, clay, and iron oxides.

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