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# WELDED TUFF FROM DEEP-WELL CORES FROM CLINCH COUNTY, GEORGIA*

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ABSTRACT

A suite of drill cores from a depth of about 4,000 feet from Clinch County, southeastern Georgia, merits description because the cores disclose a type of volcanism not previously recognized in the region, and also because they contribute to the much broader story of igneous activity in the Georgia-Florida region.

The record of volcanism begins with a fine-grained volcanic conglomerate composed of andesite and welded tuff fragments of dacitic character. These are partly rounded and have been transported to their present position. Above the conglomerate is about 35 feet of rhyolitic welded tuff which represents deposition directly from an ash flow, which has been replaced by laumontite. Above the ash flow tuffs is a recurrence of the transported volcanic conglomerate materials.

Low-grade metamorphism has affected the volcanic materials, but without detracting from the relationships.

## INTRODUCTION

A deep well drilled in southeastern Georgia in 1952 presented an excellent set of drill cores extending through volcanic materials. The cores became available for study by the U. S. Geological Survey and were referred to me by the late Josiah Bridge. The well is known as the Lem Griffith's well No. 1 and is in Clinch County, Georgia, about 12 miles east of Fargo.

The cores of the Clinch County well merit description because they disclose a type of volcanic activity not previously recognized in the region, and also because they contribute to the much broader story of igneous activity in southeastern Georgia and much of Florida. The wide extent of deeply buried volcanic materials in the Georgia-Florida region has been revealed in the course of investigations of possible oil resources, and we have to thank the oil geologists connected with these studies for much valuable information.

The core samples of the Clinch County well extended from a depth of 3,981 to 4,119 feet, and present about 138 feet of volcanic materials. Drill cuttings were available for study from depth ranging between 3,830 and 3,870 feet, and between 4,330 and 4,470 feet. Electric log characteristics and a study of cutting samples by Esther R. Applin, U. S. Geological Survey (personal communication) indicated that rhyolitic rocks were penetrated at a depth of about 3,843 feet.

Three types of volcanic materials are recorded in these cores. These

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and the overlying and underlying clastic and detrital materials may be briefly described as follows, beginning with the lowermost available materials.

Most of the chips from drill cuttings between 4,470 and 4 330 feet are shalelike material, composed of different proportions of igneous detrital debris, but a few represent volcanic rock fragments. The significance of the volcanic fragments is not clear, as they may represent material derived from higher levels. However, one core sample taken at a depth of 4,348 feet was a fine-grained dense black shale with no recognizable ash shards. Microscopic examination of this and the chip samples of shale indicated only slight metamorphism and no significant characteristics.

The lowermost core sample in the interval 3,981 to 4,119 feet is composed of andesitic and dacitic volcanic rock fragments. Many of these, in particular the dacitic ones, are partly rounded. The aggregate of volcanic debris is best described as fine-grained volcanic conglomerate. The petrology of these rocks will be discussed in the following section.

The material lying between 4,101 and 4.059 feet represents rhyolitic welded tuff. However, the lower 9 feet of this section is composed of a mixture of the andesitic and dacitic materials and rhyolitic welded tuff. The materials lying above the welded rhyolitic tuff (4,057 to 3,986 feet) show several lenses of fine volcanic conglomerate similar to that in the lower part of the section. Other parts are best described as a shalelike volcanic graywacke. The volcanic conglomerate reoccurs at intervals up to at least 3,830 feet, with finer detrital material intervening. Some thin sections show a dominance of plagioclase grains which seem to have been derived from the andesite rock source.

## Petrology of the Clinch County Cores

The fine-grained volcanic conglomerate is composed of andesite and dacite rock fragments that have been transported and so intimately intermixed that their relative age is indeterminable.

### *Andesite*

The andesite rock fragments range in size from a fraction of a millimeter up to about 4 mm. in diameter. Some have a very fine-grained trachytic texture and others contain plagioclase crystals as much as 1 mm. in diameter. Free plagioclase grains of equal size are abundant, especially near the upper part of the drill core. The free crystals are in part euhedral in outline but many of them are angular. The feldspar has undergone alteration as described in a later section of this paper. Ferromagnesian groundmass material has altered to dark pigment, and a few altered ferromagnesian phenocrysts are now a serpentinelike material. Some of the andesite fragments contain spherical gas cavities now filled with celadonite or chlorite. Abundant minute areas of leucoxene indicate that the andesite originally contained finely disseminated ilmenite. The andesite rock fragments show none of the welded tuff structures that characterize the dacite.

*Dacite*

Rock fragments of dacitic character form a large but varying proportion of the detrital materials both below and above the welded rhyolite

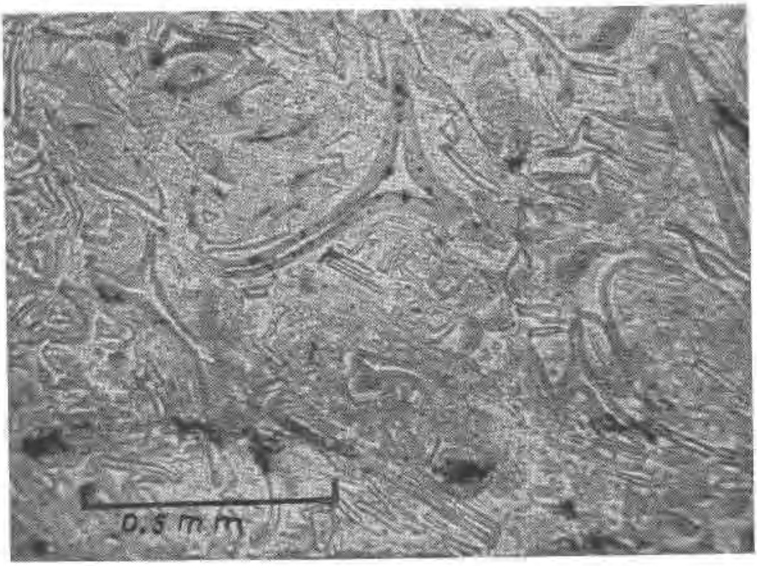


FIG. 1. Welded tuff from a deep well, Clinch County, Georgia. Dacitic welded tuff. The zoned structure resulting from devitrification and the development of cristobalite and feldspar is well represented in the central shard.

tuff. These rock fragments are as much as 5 mm. in diameter, and commonly show distinct rounding. The color is usually a cinnamon buff (Ridgeway). A wide variety of the structures commonly characterizing high-silica volcanic rocks is observable and includes fragments of large spherulites, fine grained aggregates of spherulites, and fragments characterized by swarms of fine grained lathlike plagioclase crystals that give a trachytic structure. The most significant fragments are those that show welded tuff structure as illustrated in Fig. 1. The shards there represented are without distortion, but in most of the grains there is marked compression and distortion of the ash structure. A few grains show distortion of pumice grains. The shards retain the axiolitic structure resulting from a fine grained parallel intergrowth of feldspar and cristobalite. Whether any cristobalite remains is problematical. In some of the shards a welded tuff structure may have been destroyed during devitrification, which occurs as a result from the development of spherulitic structures and the coarser grained devitrification products. Many of the shards show a distinct flow structure and it seems probable that both welded tuff and flow rocks are represented by the dacite rock fragments.

Most of the welded tuff fragments show the structures commonly resulting from the disruption of roughly equidimensional glass bubbles, and include lune-shaped fragments, cusps bounded by segments of three contiguous bubbles, curved plates, and pumice fragments. In many rock fragments there has been marked compression and alignment of the shards, but these retain distorted traces of the aforementioned ash structures. The dacite differs from the andesite in the absence of phenocrysts in most of the rock fragments. Sparse plagioclase phenocrysts are now sodic, but the extent of change due to alteration is unknown. The crystal habit suggests that they were more sodic than the abundant plagioclase phenocrysts of the andesite. Quartz phenocrysts are rarely present. No ferromagnesian silicates are observable, either as phenocrysts or in the groundmass.

*Welded rhyolite tuff*

The core samples lying between 4,101 and 4,057 feet comprise the second type of welded tuff. This horizon differs in essential ways from the horizon below and above, and is characterized by material of distinct petrographic character. The basal part of this horizon, lying between 4,101 and 4,092 feet, contains a large proportion of the dacitic and andesitic fragments previously described. Evidently the ash flow emplacing the rhyolite welded tuff overrode the unconsolidated materials below and incorporated a large proportion of them into the basal part of the rhyolite ash flow. The rhyolite type of shard fills interstices between the andesite-dacite rock fragments. The shards of this interstitial ash material were derived from fractured glassy bubble walls and show only moderate distortion, but collapsed pumice fragments were much more plastic and lenses of pumice bend around and are constricted between rock fragments.

The upper 35 feet of the welded tuff section (4,092 to 4,057 feet) represents almost pure rhyolitic shard material. Most of these shards have the forms resulting from the disruption of a vesiculated glass, as illustrated in Fig. 2. These comprise arcs of bubble walls, slightly curved plates, cusps bounded by arcs of circles, and Y shaped fragments representing the juncture of three bubbles. Unbroken bubbles are not rare.

Platelike shards derived from ruptured pumice fragments are also present, and a few pumice fragments show distortion as in the lowest part of the welded rhyolite. Between these shards is a matrix material representing volcanic dust. The shards have dimensions of the order of 0.4 mm and represent a rather coarse-grained ash.

Phenocrysts of feldspar and quartz form only a few per cent of the rock. The feldspar is clouded by minute flakes of sericitic mica. The plagioclase has no doubt become more sodic by alteration as discussed in

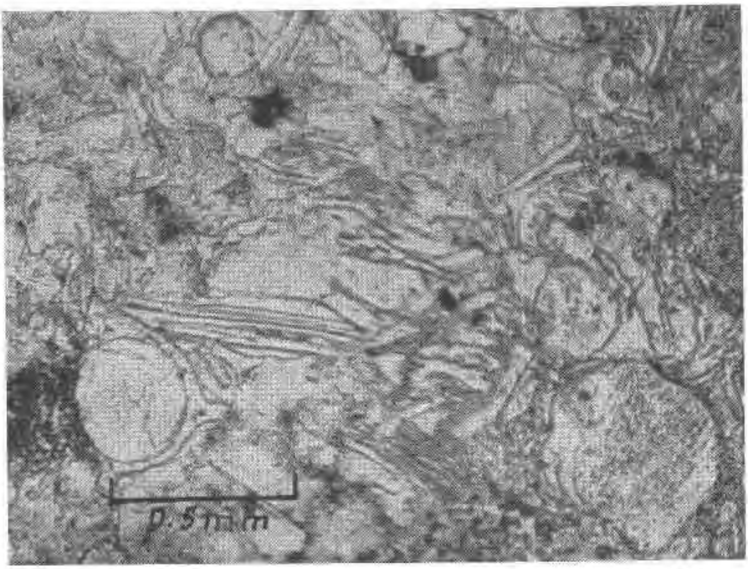


FIG. 2. Welded tuff from a deep well, Clinch County, Georgia. Rhyolitic welded tuff. The original glass of the shards has been replaced by a single unit of laumontite that covers most of the area of the figure.

the section on alteration. Some of the feldspar was probably sanidine. No ferromagnesian phenocrysts are present, and the rock represents a typical welded rhyolite tuff.

The shards were originally glass, but in the upper part of the section have been replaced by laumontite, which has been identified by its $x$-ray and optical properties. In the lower part of the section the shards have been replaced or partly replaced by a very fine grained chertlike form of quartz.

*Overlying volcanic detrital materials*

The materials lying above the rhyolite welded tuff are in part made up of grains of dacite and andesite, vary greatly in size up to 4 mm. or more in diameter, and represent a fine grained volcanic conglomerate.

Thus they are not different from the materials lying below the rhyolite welded tuff. However, much of this overlying material resembles shale in the hand specimen, but microscopic examination shows that it is composed of rock and mineral grains of the order of 0.1 mm. in diameter, with much fine grained interstitial material. Rock grains similar to those of the fine grained conglomerate are present, but the proportion of feldspar is large, greatly exceeding the angular quartz grains. Thus it seems evident that an andesitic rock provided a large proportion of these mineral grains. The quartz may in part represent material derived from sedimentary rocks.

## Alteration

*Andesite-dacite volcanic agglomerate*

The lenses characterized by andesite and dacite rock fragments were crystalline in mineral composition, in part lithic tuffs and in part devitrification products. In contrast, the rhyolite shard fragments were glassy (vitric) at the time of alteration. This difference in composition resulted in somewhat different alteration products in the conglomerate and the rhyolite tuffs and these will be discussed separately. The fine grained volcanic conglomerate lenses above and below the welded rhyolite tuff are made up of the same rock grains and do not differ in alteration products.

The order of formation of alteration products is not clear, and, possibly most of them formed at essentially the same time. The following secondary minerals associated with andesite-dacite rock debris have been identified: albite (albitized andesine), sericitic mica, epidote, pumpellyite, calcite, quartz, celandonite, saponite, chlorite, hematite, and leucoxene.

The plagioclase is clouded by minute grains of sericitic mica, and indices of refraction are in general less than 1.540. This indicates that the plagioclase has all undergone albitization, probably of andesine in the andesite, and perhaps oligoclase in the dacite. The relationships are similar to those described by Coombs (1954) in his detailed study of the alteration of volcanic tuffs in New Zealand. Like the Clinch County materials, they were dominantly volcanic in origin. In discussing plagioclase, Coombs (1954, p. 71) states, "In the vast majority of North Range rocks phenocrystic plagioclase is uniformly low-albite, composition $An_{0.4}$. Such grains are always faintly clouded and contain scattered flecks of sericite. . . there can be no doubt that such albite owes its uniform, lime-free composition to albitization of andesine. . . ." All the alteration products in the Georgia materials including the sericite seem to have developed under low-temperature conditions suggesting that the sericitic material is a hydrous mica.

Epidote in aggregates up to 0.3 mm. in diameter is abundant in some of the cores, and pale-green prisms of pumpellyite, identified optically by R. L. Smith, U. S. Geological Survey, are sporadically associated with epidote. Calcite forms irregularly shaped areas in varying proportions in all the cores. In one specimen, a fragment of limestone is included with the other rock fragments, but fragments of sedimentary rock are rare. The abundant but very small grains of leucoxene in the andesitic fragments were no doubt derived from ilmenite. Magnetite grains are sparse and magnetite seems to have been much less abundant than ilmenite in the andesitic rock. On the other hand the dacitic rock fragments contain almost no leucoxene, but do contain more dustlike magnetite than do the andesite grains. Quartz fills interstices between rock fragments and has partly replaced tuff material in the lower 10 feet of the welded rhyolite. It forms very minute grains of secondary quartz, almost resembling those of chert in some of the specimens.

The group of minerals—celadonite-saponite-chlorite—is of special interest. Celadonite, where still persisting, is recognizable by its bright-green color and high birefringence. In some specimens it is surrounded by a narrow outer film of saponite—a common relationship of these minerals. However, most of the green cavity-filling materials is now chlorite with the low birefringence and blue color at the position of extinction (strong dispersion of the axes) characteristic of many chlorites. This chlorite fills vesicular pore spaces as does typical celadonite and has the same zonal grouping of radial aggregates. The color is lighter, duller green than that of the celadonite. Some specimens show a partial alteration of celadonite to chlorite. Therefore, it seems evident that much of the chlorite was derived from celadonite. Celadonite is an iron-magnesium member of the mica group and its alteration to chlorite, in analogy with the well-known alteration of biotite, is not surprising. Chlorite also forms as fillings in the pore spaces of originally glassy pumice, as replacement material in some of the very fine grained andesitic rock grains, and as interstitial material in the very fine grained shalelike graywacke. It may have formed directly as chlorite.

*Rhyolitic welded tuff*

The rhyolitic welded tuffs were no doubt altered under physical conditions no different from those of the andesitic-dacitic materials; but their lower ferromagnesian content and the glassy character of the shards at the time of alteration resulted in a somewhat different relationship among the alteration products. The following alteration products have been identified in welded rhyolite tuff: saponite, celadonite, chlorite, epidote, laumontite, and quartz.

The characteristic alteration product of the rhyolite welded tuff is laumontite. In the hand specimen it is "flesh-ocher" (Ridgeway).

Coombs in his study of the aforementioned tuffs in New Zealand described laumontite, one of the important alteration products, as being buff colored. Laumontite is present in all but the basal portion of the rhyolite welded tuff that contains a large proportion of andesite and dacite rock fragments. The overlying 35 feet of tuff is all characterized by laumontite, and some horizons are almost wholly that mineral. It forms irregular areas up to 3 mm. in diameter, and so large areas of shard material are poikilitically enclosed in laumontite. In the lower part of the welded rhyolite tuff the shards have been in part replaced by very fine grained chertlike quartz, obscuring the shard structure more than has the replacement by laumontite.

The original composition of the plagioclase of the welded rhyolite tuff is problematical; but the plagioclase is now albite, and like that from andesitic rocks contains clouds of minute sericite grains. Therefore, it seems evident that it also has undergone albitization. The celadonite filling vesicular cavities with an outer rim of saponite is far less abundant than in the andesitic-dacitic tuffs, but shows the same relationships. Epidote is fairly abundant in small aggregates or in single nearly euhedral crystals.

The welding of a tuff immediately follows ash flow emplacement, and seems to have been closely followed by devitrification. Hence both processes involve heat from a magmatic source. The rhyolite tuff was emplaced by an ash flow and shows welding and therefore the question arises as to the possibility of magmatic heat contribution to the production of secondary minerals in the Clinch County well. The study by Coombs of the development of a similar group of minerals in New Zealand rocks suggests an answer to that question. The materials there had all undergone transportation and redeposition, and the only heat source considered by Coombs (1954, p. 91–93) was that resulting from depth of burial. Thus magmatic heat was not a factor in the development of the low-grade metamorphic minerals in New Zealand and this strongly suggests that the same group of minerals developed independently of magmatic heat in the Georgia materials. This conclusion would definitely include the laumontite and heulandite of the New Zealand rocks and seemingly also the laumontite of the Georgia rocks—that is, welding and devitrification and the development of low-grade metamorphic materials are entirely distinct episodes.

## Regional Relationships

Volcanic rocks, including rhyolitic lavas, tuffs, basalt and volcanic agglomerates were reported from the Georgia-Florida wells discussed by Applin (1951, p. 8). These reports suggested the restudy of available materials from these wells and the restudy confirmed the earlier reports. All these materials had undergone much more alteration than those of the Clinch County well. However, the wide occurrence of volcanic agglomerate or conglomerate, probably similar to that in the Clinch County well, seems to be indicated. A core sample from Camp No. 1 well of the Sun Oil Company, Marion County, Florida, revealed well-preserved shard and pumice structures at a depth of 4,618 to 4,653 feet. The rock shows the development of zones of sericite that partly obscure the relationships, but actual welding seems to be indicated. The Jameson well No. 1, Hillsborough County, Florida, showed welded tuffs in three core samples taken between 10,010 and 10,034 feet.

The Marion County well lies about 125 miles nearly south of the Clinch County well, and that in Hillsborough County near St. Petersburg, about 200 miles south-southwest. Of course the correlation of horizons and continuity of occurrences is quite impossible with the scant information available. All we definitely know is that there is a wide occurrence of volcanic materials in the Georgia-Florida region and that welded tuffs constitute an interesting part of this wide-spread volcanism.

## Geologic Age

Applin (1951, p. 11) states that, "As a working hypothesis . . . the age of these volcanic rocks is tentatively classified as early Paleozoic or possibly Precambrian." Below the volcanic rocks of the Clinch County well are several hundred feet of unmetamorphosed shalelike material, and hence it is very improbable that they are Precambrian in age. These unmetamorphosed materials suggest that the volcanic rocks of the Georgia-Florida region were laid down in early Paleozoic time as Applin strongly implies.

The andesitic and the dacitic materials were derived from rocks that were undergoing erosion, and hence represent volcanic episodes earlier than the one represented by the welded rhyolite. However, there is no indication of how much earlier. These rocks may be of essentially the same age as the rhyolitic welded tuff, or they may be Precambrian.

## References

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