PETROGRAPHY AND ORIGIN OF THE 111 RANCH CHERTS, GRAHAM COUNTY, ARIZONA[1]

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ABSTRACT

The 111 Ranch Beds are a sequence of middle Pleistocene flood-plain, paludal, and lacustrine deposits exposed in a badland topography approximately 14 miles southeast of Safford, Ariz. Both bedded and nodular chert varieties occur in the area. Massive-bedded chert is confined to the upper part of the section and is generally interbedded with a thick diatomite unit. Thin lenses of chert are generally confined to the bedding planes of the various limestone units.

The two possibilities for the source of the original silica are: (1) alteration of tuffaceous sediments, and (2) chemical weathering of the volcanic Whitlock Hills. The silica was accumulated by diatoms and was subsequently reorganized into chert.

INTRODUCTION

The 111 Ranch Beds are a sequence of middle Pleistocene sedimentary rocks exposed in a badland topography. The geographic location is approximately 14 miles southeast of Safford, Ariz., and just north of the volcanic Whitlock Hills near the intersection of the Gila and San Simon Valleys in T. 8 S., R. 28 E.

A stratigraphic section (fig. 1) of the area shows the general character of about 200 feet of sediment exposed in the 111 Ranch basin. Clay marl, silt, and tuffaceous silt dominate this section. Fossil content and the fine-grained but poorly sorted character of these sediments suggest deposition in a paludal flood-plain environment.

Three of the limestone units are believed to be of lacustrine origin, and all contain chert. The Lake Nancy Limestone unit 6 is a key stratigraphic unit because it is the most extensive and continuous deposit in the 111 Ranch area. Ed's Limestone unit 3 is of minor consequence with limited exposures.

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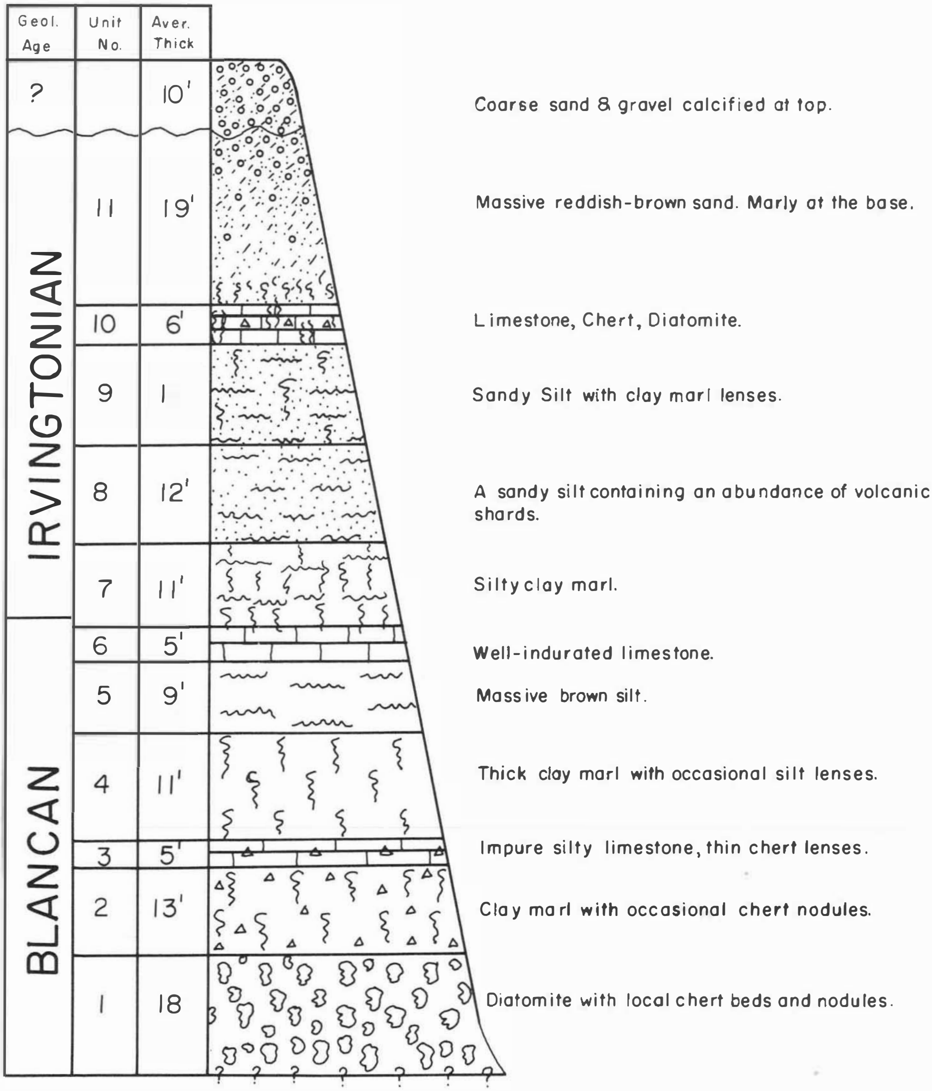

Figure 1. --Composite stratigraphic section of the 111 Ranch Beds.

The Capybara Limestone unit 10 is of varied lithology, consisting chiefly of limestone, but it grades into a massive diatomite near the Whitlock Hills. Interbedded with the diatomite, and almost always near the center of the unit, are thick beds of green chert.

GEOLOGIC OCCURRENCE OF THE 111 RANCH CHERT

Both bedded and nodular chert varieties occur in the area. Massive-bedded chert is confined to the upper part of the section and generally is interbedded with a thick diatomite unit. This diatomite is a facies of the Capybara Limestone unit 10 (fig. 1). The thickest portion of the diatomite is about 20 feet, of which 15 feet is composed of cherty material.

This chert-bearing diatomite crops out in the southeast and southwest portions of the 111 Ranch area and rims the lower parts of the older Whitlock volcanics. When traced northward, away from the Whitlock Hills, the diatomite quickly grades into massive limestone, which makes up the bulk of the correlative unit. Most of the younger units of the section, be they sand, silt, clay, or limestone, become diatomitic and locally contain thin lenses of chert when traced to the southeast. In the extreme southeast corner of the area, abutting the Whitlock Hills, the entire section up to the units overlying the Capybara Limestone unit 10 becomes a rather pure diatomite. Apparently, here was an area of permanent or near-permanent water. The Capybara chert is thickest in this area and presents the most massive appearance. The diatomites below the Capybara level also contain chert beds, but they are thin bedded, averaging 3 to 6 inches in thickness. All the chert is yellow green when wet.

In the basin, most chert is rather thin bedded and found along bedding planes or in solution cavities in the limestone units. When traced northward away from the diatomite beds, the chert layers lens out usually by becoming slightly nodular. Much of the massive Capybara chert protrudes as irregular but connecting knobs on outcrops, suggesting that at one time it consisted mostly of nodules, which coalesced into bedded lentils. These knobs and the more isolated nodules of chert in the limestone are probably apophyses of larger masses of chert and not individual concretions. The close association of diatomite with the chert beds, including those thin ones that lens out within limestone a short distance from the diatomite, clearly indicates a genetic relationship between the diatoms and the chert. Moreover, since diatomite is found only in contact with the Whitlock volcanic rocks, a genetic relationship is implied between the volcanic rocks and the diatomite.

The Kiln Diatomite unit 1 (fig. 1) is the oldest exposed unit in the 111 Ranch beds and is exposed only in the southwestern portion of the mapped area. However, it does crop out in the adjacent area to the west along the Whitlock Hills, where it contains chert in thin nodules or bedded lenses, the thickest of which does not exceed 2 feet. Massive chert is confined to the younger Capybara unit. Thin-section work on the diatomites (Mathias, 1959) reveals these siliceous units to be rather high in diatom content, 75 to 90 percent, the purest being the Kiln unit. Although Mathias found no tuff fragments in his studies, the writer feels that some were present but have been altered beyond recognition. This is indicated by the abundance of volcanic shards just northeast of the mapped area, along with the shardy appearance of the siltstone units exposed in the 111 Ranch basin. Differential thermal analysis of the chert reveals montmorillonite to be the sole clay present. This clay could have been produced during alteration of the tuffaceous material.

PETROGRAPHY OF THE CHERT

Although cherty rocks form a minor part of the 111 Ranch Beds, they are of interest because the origin of chert is a classic geological problem. Major questions are silica source and time of origin.

Chert has been divided into two petrographic end members (Folk and Weaver, 1952), which are (1) microcrystalline quartz, and (2) chalcedonic quartz. Microcrystalline quartz forms the bulk of most cherts and consists of subsequent interlocking grains in random orientation. The individual grains are rather small, averaging from 3 to 5 microns in diameter. Chalcedonic quartz appears to be composed of sheaflike bundles of fibers of not more than a few microns in length, although they may range up to several hundred microns. Specific gravity and indices of refraction of chalcedonic quartz are lower than those of quartz, but their essential identity is shown by the tendency of the two to grade into one another.

Microcrystalline and chalcedonic quartz can be formed by either replacement or direct precipitation. The controlling factor of mineral species depends on spacing and distribution of crystallization centers. According to Folk and Weaver (1952), most microcrystalline quartz forms by replacement, and almost all directly precipitated cavity fillings are composed of chalcedonic quartz.

Microcrystalline quartz is the mineral species most prominent in the 111 Ranch cherts. However, in many cases the grains are so small that the material appears nearly isotropic. Chalcedonic quartz is secondary in importance. Opal is also present but in very minor amounts; it generally rims small cavities and trends visibly to fibrous or spherulitic chalcedonic quartz. The opal is in such small amounts that it does not affect the general physical properties of the chert.

Thin sections of chert associated with diatomite usually display a few partially dissolved tests of diatoms, whereas none were observed in thin sections of chert occurring within limestone. However, the latter chert does contain relict calcite scattered throughout the sections as wisps or isolated crystals, usually concentrated in random areas, but never in abundance or large solid aggregates. Some bone matter associated with limestone shows almost complete replacement by silica but still contains wisps of what must have been the original fossilized material. The fossils are evidently pre-chert, and silica replacement of bone matter probably occurred simultaneously along with the replacement of the limestone.

RELATIONSHIP OF DIATOMS TO SILICA PRECIPITATION

Specialized conditions are required for prolific diatom growth and their accumulation into concentrated deposits. The more suitable these conditions are the more accelerated will be the accumulation of diatomaceous sediments. The lake waters in which the diatoms were growing must have been relatively clear, containing nutrient solutes and a plentiful supply of silica.

Diatoms appear to favor neutral or slightly alkaline pH environments, which act directly on their physiological processes. This may be one factor in explaining the separation of the limestone facies from the diatomaceous facies in the Capybara unit; apparently, the waters of the interior of the lake had a higher pH, which resulted in precipitation of $CaCO_3$, while the shoreline areas retained a neutral or slightly alkaline pH value favorable to diatom growth. By extracting the silica from the host waters, the diatoms were quite capable of exhausting the supply.

SOURCE OF THE ORIGINAL SILICA

Two major sources of original silica are presented as possibilities. They are: (1) alteration of tuffaceous sediments, and (2) weathering of the volcanic Whitlock Hills.

Bramlette (1946) has explained at length the relationship of tuffaceous sediments to large accumulations of diatomaceous beds. In his description of the Monterey Formation, he has shown that the close association of diatomaceous beds with tuffs indicates that tuff is an important source of silica for diatom growth.

Petrographic examination of the sediments of the 111 Ranch Beds shows that tuffs are present in most of the units, particularly in the upper part of the section. The amount of pyroclastic material varies throughout the column but seems to have reached its climax during deposition of unit 8 (fig. 1). This unit is characterized by an abundance of shardy material mixed with other clastics. Although most of the volcanic ash probably fell into the mapped area, the surrounding areas also received an abundance of tuffaceous sediments. Some of this material must have been reworked and carried into the 111 Ranch area by fluvial and aeolian processes.

During the process of chemical weathering, the residual tuffs were, in part, altered to bentonite. Alteration of volcanic ash released a considerable amount of silica into the lake waters, which existed during the depositional period of the 111 Ranch basin. Concentration of some of this silica was in turn due to the biochemical action of the diatoms growing in the southern part of the area.

Diatomite beds are found only adjacent to or near the older volcanic Whitlock Hills. The lensing of these beds away from the hills can be easily traced in the field. Such a close association suggests a genetic relationship. Indeed, this small range may have been an important source of original silica. Chemical weathering of the older volcanics must have released much silica, which was utilized for the life processes of the diatoms. That chemical weathering was predominant in abstracting silica from the Whitlock Hills is shown by the almost complete lack of coarse detritus in the adjacent diatomite beds, which actually lap against these older volcanics.

In summary, the two possibilities for the source of the original silica are: (1) alteration of tuffaceous sediments, and (2) chemical weathering of the volcanic Whitlock Hills.

ORIGIN OF THE 111 RANCH CHERTS

The striking similarity between the cherts and diatomites in such details as detrital content and very fine laminations that are continuous across contact zones clearly suggests a genetic relationship. The vertical gradation of the massive cherts of unit 10 into diatomite suggests that the cherty rocks were formed from the diatomaceous facies by alteration involving concentrations of silica into denser beds. There is little doubt that the silica probably derived from the sources mentioned was accumulated by the thriving diatoms of the 111 Ranch area. When alive, the organisms protect their siliceous skeletons from dissolving with films of organic matter. After their death, the protective action would no longer be effective, and the silica would slowly dissolve. It is then suggested that as compaction began to take effect the interstitial waters presumably became saturated with silica derived from solutioning of some of the tests. Solution probably took place at thinner edges and joints of the skeletons, and deposition on flatter surfaces, where it eventually consolidated into chert.

The presence of chert in bedding planes and fissures of the limestone units also adds to the theory of a secondary origin. The limestone cherts are probably slightly younger than the more massive ones of the diatomite beds. Since the exact origin of the limestone cherts is still not clear, the following process is again suggested. Because the permeability of the limestone is lower than that of the diatomite, passage of the interstitial waters saturated with silica was impeded at the diatomite-limestone contact zone. In the diatomite there is an abundance of small plant stems. This may indicate that, during decay, the pH values of the interstitial waters of the siliceous beds were lowered beyond the neutral zone, thus forming a medium in which calcite would become unstable. This resulted in solution of $CaCO_3$ along cracks and bedding planes, thus affording a conduit for the silica-saturated waters. Limestone was replaced with silica, which eventually hardened into chert. The abundance of relict calcite as seen in the chert thin sections substantiates this theory. Additional evidence for the secondary nature of the limestone cherts lies in the silicification of fossil remains associated with both the chert and host limestone.

TIME OF REPLACEMENT

There is vague but indicative evidence that solution of the diatoms occurred early in the compaction stage. In the field where small upwarps and downwarps are encountered and chert is present, the chert is as much deformed as the encasing host rock. This seems to indicate that the chert was well formed before intense compaction occurred, and it would thus be an early constituent of the diatomite. The chert associated with the limestone was probably formed shortly after or contemporaneously with the massive chert of the diatomite beds.

CONCLUSIONS

1. The chert of the 111 Ranch Beds is of secondary origin and was, for the most part, derived through diagenesis of the diatomaceous beds.

2. Original silica was derived through alteration of tuffaceous material and from the chemical weathering of the Whitlock Hills.

3. This silica was then concentrated through the biochemical action of thriving diatoms.

4. Time of chert formation was probably early in the compaction stage of the diatomite.

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