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PERMIAN STRATIGRAPHY OF THE DEFIANCE PLATEAU ARIZONA

by

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INTRODUCTION

In recent years some rather sweeping nomenclatural changes have been proposed for certain Permian sedimentary rocks in parts of both New Mexico and Arizona (Baars—1962). A response to those proposals applicable to the Defiance Plateau was published and it was concluded that Baars' treatment of the Permian stratigraphy of the Defiance Plateau is fundamentally unsound (Peirce—1964). I welcome this opportunity to review and update the subject and to present proposals developed by combining unpublished data with the contributions published by previous workers.

GENERAL STATEMENT

As has been emphasized often, the Defiance Plateau is an island of Permian strata in a sea of Mesozoic sedimentary rocks. Not only is the Defiance region isolated from other regions of Permian exposures (Mogollon Rim 100 miles to the southwest and the Zuni Mountains 30 miles to the southeast), but the exposures on the Defiance Plateau, limited as they are to deep canyons, also suffer from lateral discontinuity.

On the Defiance Plateau, approximately 1200 feet of outcropping Permian strata overlie Precambrian metamorphic, igneous, and sedimentary rocks (Lance—1958). The lower portion consists of "red beds" that have been variously equated with the Cutler, Supai, Abo, and Yeso formations. However, it is the upper portion, a sequence dominated by cliff-forming sandstones, that has attracted most of the attention given to Permian strata of the Defiance Plateau and with which this paper is primarily concerned. These sandstones have been subdivided in various ways and such terms as Upper Cutler, Lower and Upper DeChelly, DeChelly, San Andres, Glorieta, and Coconino have been applied to them.

DISCUSSION

De Chelly Sandstone

On the Defiance Plateau, lying gradationally above the red detrital rocks of the Permian Supai Formation and unconformably below Triassic formations, are conspicuous cliff-making sandstones ranging in thickness from over 800 feet at Canyon DeChelly to less than 250 feet at the southern end of the Defiance Plateau (Fig. 1). This sandstone interval, called the DeChelly Sandstone by Gregory (1917), is a composite unit; that is, it is compounded from smaller units that are differentiated on the basis of (1) nature and distribution of primary sedimentary structures, (2) color, (3) grain size aspects, (4) composition, (5) cementation characteristics, and (6) topographic expression.

Using these general criteria, it is possible to subdivide the DeChelly Sandstone into five units. (Table 1). Each is not equally developed at all localities; indeed, all five are not developed at any single locality, with the possible exception of Bonito Canyon. Only after the DeChelly Sandstone is subdivided into its integral parts is it possible to constructively speculate not only as to its relationships to Permian stratigraphy away from the Defiance Plateau, but as to its local internal relationships as well. The names or handles applied herein are neither sacred nor important except as they might aid in depicting relationships and point a finger at phenomena that deserve the consideration of those interested in this general problem.

The relationships between the five described units are shown in Figure 1. At the outset, two principal observations should be made: (1) the interval between the Permian Supai or Supai-Yeso "red beds" and the Triassic Shinarump or Moenkopi strata thins from approximately 800 feet at the type area of Canyon DeChelly to less than 200 feet in the subsurface at the south end of the Defiance Plateau, most of the thinning having taken place on the Plateau itself; and (2) each unit has a pinch out somewhere within the Plateau which emphasizes the composite nature of the sequence and suggests the need to evaluate the local relationships before attempting regional correlations.

The subdivisions of the DeChelly Sandstone outlined in Table 1 are manifestations of shifting environments of deposition—environments that are naturally grouped together in space and time but which transgress and regress in response to external factors. Lateral relationships are a problem, but in such a setting are probably near gradational for the most part.

White House Member

In the type area of Canyon DeChelly, underlying the Triassic Shinarump Member of the Chinle Formation, it is the White House Member (about 570 feet thick) that forms the impressive sheer canyon walls. Approximately 95% of its thickness consists of 25 cross-stratified eolian units having an average thickness of 21 feet. The remaining 5% consists of 11 horizontally stratified, water-deposited, truncating units having an average thickness of 3 feet.

TABLE 1. SUBDIVISIONS OF THE DE CHELLY SANDSTONE OF THE DEFIANCE PLATEAU

DE CHELLY SANDSTONE (Peirce, 1962; 1964)		REMARKS
Ft. Defiance Member (0 - 105)	Sandstone and siltstone, interbedded; dark-reddish-brown to pale reddish-brown; small to medium scale cross-stratification and horizontal stratification, aqueous ripple marks; forms a ledgy slope.	Moenkopi of Darton (1925); "Red beds" of Baker and Reeside (1929), McKee (1934), and Balk (1954); San Andres equivalent of Baars (1962).
Black Creek Member (0 - 225)	Sandstone; grayish-orange to moderate orange-pink; interbedded medium-scale cross-stratified and horizontally stratified sandstones; an orthoquartzite of mixed environmental type; forms a cliff.	Upper DeChelly of Read & Wanek (1961); Glorieta or Coconino of Read (1951); Glorieta of Baars (1962); "Coconino-like" sandstone of McKee (1934) at Bonito Canyon.
White House Member (0 - 570)	Sandstone; pale reddish-brown to moderate reddish-orange; large-scale cross-stratification, flat truncation surfaces frequently overlain by thin, water-worked sandy siltstones; a subarkose of eolian origin; forms a cliff.	Principal unit in type area of Canyon DeChelly. Upper Member of McKee in type area (1934); Lumped with Hunters Point Member to form undivided DeChelly Sandstone of Baars (1962).
Oak Springs Member (0 - 128)	Sandstone and Sandstone, silty; micaceous, pale reddish-brown; horizontally stratified; water deposited; forms a slope.	Middle Member of McKee (1934) at Canyon DeChelly; Transition of Read (1951) on east flank; Yeso (restricted) of Baars (1962), Tongue of Supai of Read & Wanek (1961).
Hunters Point Member (0 - 238)	Sandstone; pale reddish-brown to moderate orange-pink; small to medium scale cross-stratification and horizontal stratification, channeling, aqueous ripple marks; a subarkose of aqueous origin; forms a cliff or slope.	Lower Member of McKee (1934) and Read (1951). Upper Cutler of Balk (1954); lumped with White House Member to form undivided DeChelly Sandstone of Baars (1962)

The water-deposited dark siltstones and silty sandstones represent local environments due, most probably, to *locally effluent water table conditions.*

Sand grains in the cross-stratified eolian sandstones have a mean diameter of .130 mm, are well sorted, and frequently contain in excess of 10% feldspar. Coarse sand grains are conspicuous when present and may range from a trace to 4% by weight of a given hand specimen. The color of this sandstone at Canyon DeChelly expresses various shades of reddish brown. Any effective cementation is due principally to quartz as overgrowths.

The White House Member is the principal component of Gregory's (1917) original DeChelly Sandstone, it constitutes the Upper Member of McKee (1934), and of Read & Wanek (1961) at Canyon DeChelly, and it forms the DeChelly Sandstone of Monument Valley 50 miles to the northwest.

Although Read & Wanek (1961) extend their Upper Member throughout the Defiance Plateau, because of contrasting characteristics on the east flank of the Plateau, I have subdivided this interval into the White House, Black Creek, and Fort Defiance Members.

Black Creek Member

In the sections on the east flank (excluding Buell Park) the White House Member is but a lower part of the "Upper Member" (Fig. 1). Peirce (1958) called attention to the fact that the sandstones constituting the upper part of the DeChelly Sandstone on the east flank are not a replica of those exposed in Canyon DeChelly. At Bonito Canyon, near Ft. Defiance, several workers have noted that contrasts exist. McKee (1934) speaks of a "Coconino-like" sandstone mixing with sandstones of DeChelly character, and Baars (1962) considers that these sandstones are to be assigned to the Glorieta Sandstone. Being hesitant to extend a regional name on to the Defiance, I refer these different-appearing strata to the Black Creek Member.

The most fundamental aspect of this unit that contrasts with the White House Member is the nature of its stratification. Throughout its extent in outcrop, horizontally stratified sandstones alternate with those that are cross-stratified on a large- to medium-scale. The horizontally stratified sandstones average from 5 to 12 feet in thickness, depending upon the section, and they form from 20 per-

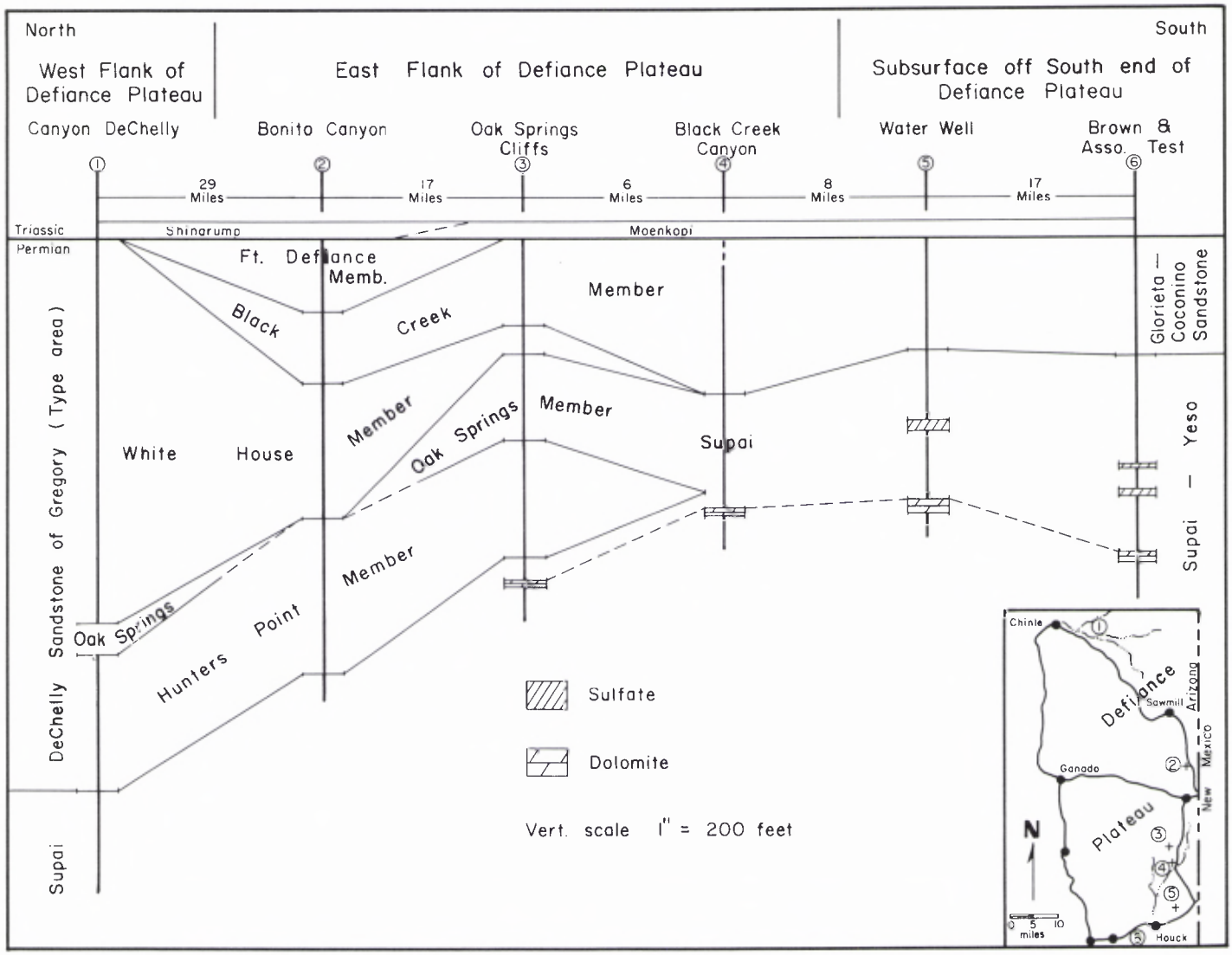

FIGURE 1
Some Permian stratal changes between the northern Defiance Plateau and the subsurface to the south

cent to 35 percent of the thickness of the member. They are without doubt water-deposited sandstones, although the particular aqueous environment is perhaps speculative. Because of this latter fact, the question of origin of the cross-stratified sandstones arises. Read (1951) speaks of "migrating beaches and bars." I suspect, however, that eolian representatives are significant such that the Black Creek Member represents a transgressive transition phase between a dominantly eolian environment to the north (White House Member) and a dominantly marine environment to the south (Kaibab-San Andres related sandstones and carbonates).

In addition to the stratification contrasts, many of the sandstones in the Black Creek Member differ from the White House Member; they are lighter in color, more highly silicified, less arkosic, cleaner (less silt-clay fraction) and are not known to contain the small fraction of coarse sand grains. There are many complexities to explaining the significance and origin of these various contrasting phenomena. However, many can be attributed to processes of reworking, diagenesis, etc., without invoking differences in ultimate source areas.

The Black Creek Member does not have a recognized sharp boundary with the underlying White House Member. It is perhaps best described as gradational, such that the placing of a contact is somewhat arbitrary. One can observe the distinctive end members and then, for one reason or another, be hard pressed to define a specific contact.

The fact that the Black Creek Member gradationally overlies the White House Member to the south of Canyon DeChelly is important in evaluating Baars' correlations on the Defiance Plateau. It is his concept that the Yeso Formation (restricted) occupies a stratigraphic position between his Glorieta (Black Creek Member) and DeChelly (White House Member—in part) sandstones but that at

Bonito Canyon and Canyon DeChelly the Yeso Formation (restricted) had been removed by erosion prior to the deposition of the Glorieta Sandstone (Fig. 2). However, relationships at the Oak Springs Cliffs section (not included by Baars) prove conclusively that the position of his Yeso Formation (restricted) is stratigraphically below the White House Member, not above it (Figs. 1 and 2). He used this nonexistent unconformity to conclude that the Coconino-Glorieta sandstones are significantly younger than the DeChelly Sandstone of the type area. This concept aided Baars in linking the entire DeChelly Sandstone with the Meseta Blanca Sandstone which forms the lower portion of the Yeso Formation in New Mexico. This led to his suggestion that "Meseta Blanca" be changed to "DeChelly" (Fig. 2).

Ft. Defiance Member

The uppermost 100 feet of Permian strata at Bonito Canyon, consisting of water-deposited sandstones and siltstones, are unlike any other part of the major sections exposed on the Defiance Plateau and are, therefore, given emphasis by naming them the Ft. Defiance Member.

In this section the Ft. Defiance Member is in sharp contact with the underlying Black Creek Member. Baars (1962) considers these strata as San Andres Limestone correlatives, a distinct possibility when it is recalled that there is evidence for the San Andres Limestone having been deposited close to if not in the area now occupied by the Defiance Plateau (Peirce—1958). There can be little doubt, too that post DeChelly–pre Shinarump erosion has unequally stripped away unknown quantities of Per-

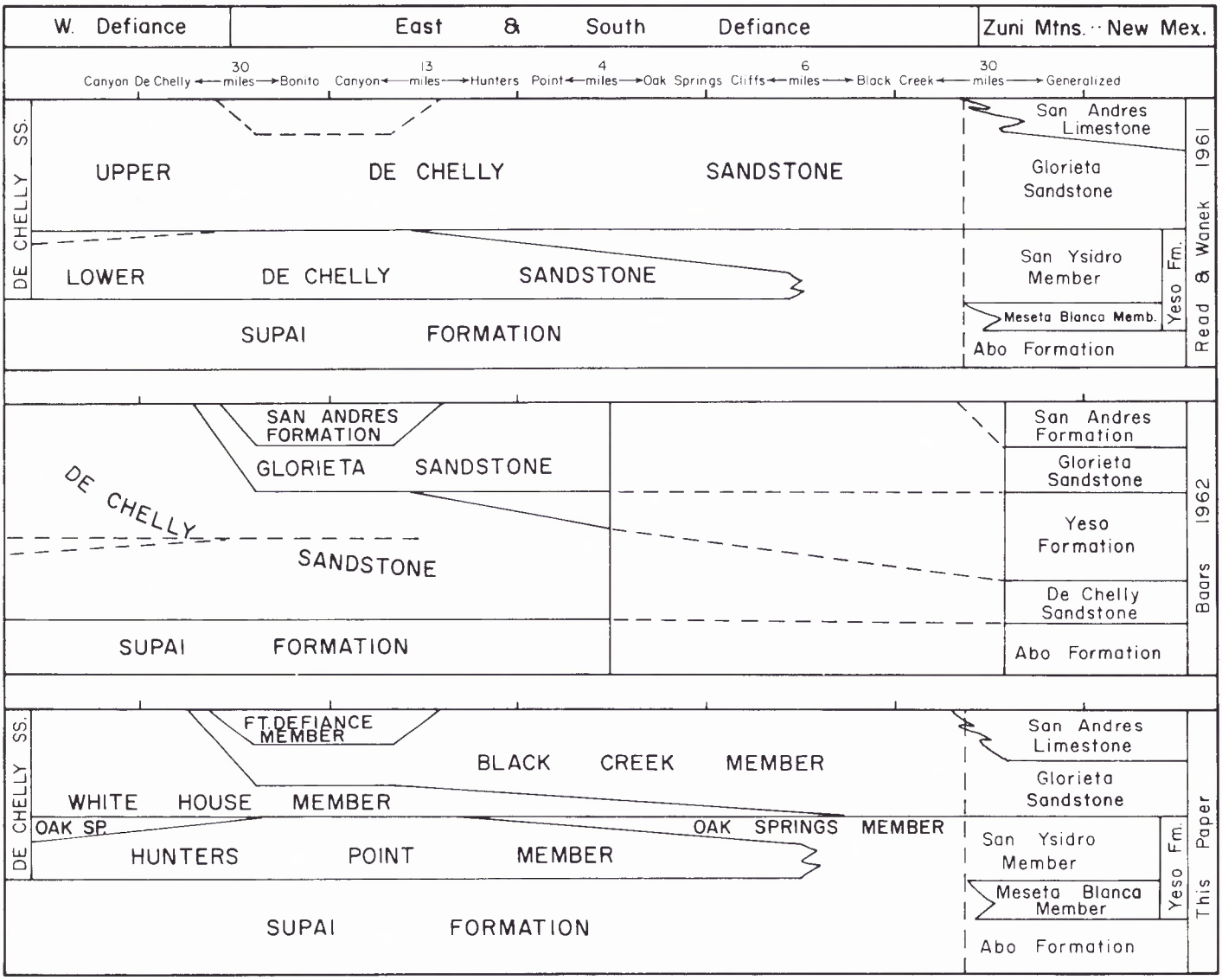

FIGURE 2

Correlations between Permian strata of the Zuni Mountains, New Mexico and the Defiance Plateau, Arizona—A comparison.

mian strata. In spite of this fact, however, the DeChelly Sandstone is thicker where it is overlain by the Shinarump than it is where it is overlain by the Moenkopi Formation.

Thus far, we have briefly discussed the stratigraphic interval that has been called the Upper Member of the DeChelly Sandstone. I have suggested that this interval needs to be examined closely if fundamental understanding is to be gained.

Oak Springs Member

In many of the sections on the Defiance Plateau the White House Member is underlain by a "red bed" unit that consists of variably micaceous, water-deposited siltstones and sandstones. McKee (1934) first isolated this unit by referring to it in Canyon DeChelly as the Middle Member. Read (1951), working on the east flank of the Plateau, referred to an analogous unit as a "Transition" and in 1961 Read & Wanek called it a tongue of the Supai Formation believing that its stratigraphic position was that of McKee's Middle Member at Canyon DeChelly. This is the unit that I am calling the Oak Springs Member and that Baars calls the Yeso Formation (restricted). However, whereas I view the unit as being stratigraphically below the White House Member, Baars considers it to be above it and that it has been eroded from the type area by a pre-Shinarump episode of uplift and removal. However, stratigraphic evidence pointed out previously, and some yet to be developed, invalidate the concept.

Hunters Point Member

Below the Oak Springs Member in many sections is a prominent sandstone unit that has attracted the attention of most workers. McKee (1934), at Canyon DeChelly, called it the Lower Member; Read (1951), working on the east flank, describes a Lower Member and Read & Wanek (1961) correlate this lower unit with McKee's at Canyon DeChelly. Further, they point out that there is a contrast in the directions of cross-stratification between the Upper & Lower Members.

Peirce (1962 & 1964), assigned the name Hunters Point Member to this lower unit and stated that the development of channels, ripple marks, and nature of cross-stratification indicated an aqueous depositional environment, thus developing further the contrast between the lower and upper sandstones. This is of basic importance because Baars, without justification beyond the superficial, correlates this unit at Hunters Point with the entire DeChelly Sandstone at Canyon DeChelly, thus violating legitimate internal stratigraphic boundaries. Because of this correlation, he was led to the conclusion that the position of his Yeso Formation (restricted) at Canyon DeChelly was in the "unconformity" at the top of the Permian section.

Yeso Formation

The Hunters Point Member is a discrete body of sandstone that, although 238 feet thick at Hunters Point, is not present at the Black Creek Canyon section 10 miles to the south. A thin dolomite (6 to 8 feet) crops out just below the base of the Hunters Point Member at both the Hunters Point and Oak Springs Cliffs sections. At Black Creek Canyon, where the lower sandstone is absent, the dolomite is 170 feet below the base of the Black Creek Member (Fig. 1). At the Oak Springs Cliffs section, the dolomite is about 300 feet below the base of the upper sandstones.

The seeming difference in stratigraphic position of the dolomite is explained by a higher rate of accumulation of the sandstones that constitute the Hunters Point Member as compared with the "red beds" that constitute the Supai–Yeso above the dolomite at Black Creek.

The thin dolomite can be followed into the subsurface where the section above it becomes more evaporitic (Fig. 1). The dolomite and sulfate units would seem to be analogous to units contained in the San Ysidro Member of the Yeso Formation in New Mexico. Baars (1962, p. 195), in reference to the Yeso Formation (restricted), states: "The dolomites, along with thin beds of gypsum, are present in the subsurface north and west of the Zuni Mountains . . ." and that "Neither the dolomites nor the gypsum are present on the southern Defiance uplift." It is to be emphasized that the dolomite unit underlies the DeChelly Sandstone. If, then, the dolomite is a legitimate "earmark" of the Yeso Formation (restricted) of Baars it is not possible for the Yeso Formation (restricted) to exclusively overlie any part of the DeChelly Sandstone.

It would appear to be stratigraphically unwise, then, to conclude that the Meseta Blanca Sandstone, which underlies the Yeso Formation (restricted) in the Zuni region, is a direct correlative of any part of the DeChelly Sandstone, let alone the upper sandstones that constitute the White House Member, as demanded by Baars' correlations.

Similarly, Baars' extension of a DeChelly Sandstone into the Mogollon Rim and Oak Creek Canyon regions of Arizona is based upon erroneous stratigraphy. This latter effort required the unnatural subdivision of an evaporite sequence, the recognition of a non-existent sandstone, and the miscorrelation of the Ft. Apache Limestone by approximately 1000 feet (Peirce and Gerrard—1966).

CONCLUSIONS

The regional nomenclatural problem is immense and any attempt to unify it is guaranteed to stiffen the backs of all "lumpers" and "splitters." Some are automatically repelled at new geologic names and others strive to sense the relationships involved regardless of the nomenclature. Concepts about the DeChelly of the Defiance Plateau have evolved to the point where it is recognized that it has parts and that some of these parts probably correlate with parts of the Supai–Abo–Cutler, the Yeso, the Glorieta, and the San Andres and Kaibab Formations. When these rough correlations are made, it is the White House Member that remains unattached, the principal part of Gregory's originally DeChelly Sandstone, which Darton (1925) subsequently called the Coconino Sandstone.

The major remaining question continues to be the relationship between these two prominent Permian units. The problem is perhaps not difficult for those who subscribe to the concept that there isn't any tangible time distinction to be made between the Coconino Sandstone

of Arizona and the Glorieta Sandstone of New Mexico. Using the vehicle of the probable Glorieta–Black Creek Member–White House Member relationships it can be stated that if the Glorieta transgresses the White House Member, then the Coconino Sandstone must do similarly. However, Baars suggested that the Glorieta is a marine equivalent of the eolian Coconino Sandstone. Although not previously emphasized in Arizona, the sandstones allotted to the "Coconino" along the eastern portion of the Mogollon Rim are not eolian in origin, therefore, not type Coconino Sandstone.

Typical eolian Coconino Sandstone transgresses the non-eolian phase with at least an easterly component. The non-eolian sandstones are believed to grade laterally into the sandstones that constitute the Black Creek Member.

It appears, then that contrasting depositional environments of approximately correlative sandstones complicate the resolution of applicable regional nomenclature. However, all available data (including subsurface) indicate that the Coconino Sandstone immediately overlies the White House Member of the DeChelly Sandstone, but with an unclear lateral relationship. It is certain, however, that the two are not separated by a Yeso Formation (restricted) as suggested by Baars. There still remains the possibility that they are one and the same sandstone body and that their differences might be largely attributable to unequally applied post-depositional changes.

However, at the present time, my own guess is that the eolian White House Member of the DeChelly Sandstone was deposited by northeasterly winds immediately prior to the accumulation of the Coconino Sandstone by northerly to northwesterly winds. Whereas the Black Creek Member transgresses the White House Member, the Coconino Sandstone transgresses suspected Black Creek Member equivalents. It seems likely, then, that the Coconino Sandstone must transgress the White House Member as well. Following this line of reasoning it is possible to conclude that the White House Member might well be more closely related to the Supai Formation than it is to the Coconino Sandstone.

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