



Pre-carboniferous paleotectonics of the San Juan Basin, New Mexico

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PRE-CARBONIFEROUS PALEOTECTONICS OF THE SAN JUAN BASIN

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INTRODUCTION

This paper summarizes and updates the state of knowledge concerning Cambrian-Devonian rock units in the San Juan Basin of northwest New Mexico and southwest Colorado. Earlier workers mapped all outcropping rock units of the Cambrian and Devonian in the Four Corners region. Since this mapping took place 20 to 25 years ago, little information has been published about the early Paleozoic rock units.

Deep wells drilled in the late 1950's and early 1960's penetrated the sequence and provided a regional understanding of the Cambrian and Devonian environments of deposition. Since then, many more deep tests have been drilled and a much more complex paleotectonic history is becoming apparent.

Figure 1 is a correlation of all Paleozoic rock units in the northern and southern San Juan Basin. Baars and Stevenson (elsewhere in this volume) discuss the Permian stratigraphy in the San Juan Basin. However, for proprietary reasons, the Mississippian and Pennsylvanian stratigraphic relationships cannot be disclosed at this time. All available mechanical logs and commercial sample logs have been used in constructing the maps and cross section illustrated in this paper. [Editor's note: see papers by Armstrong on the Mississippian and Jentgen on the Pennsylvanian elsewhere in this volume.]

STRATIGRAPHY

Precambrian

As shown in Figure 2, the Precambrian basement of the San Juan Basin is nonconformably overlain by all representative Paleozoic rock units of the Colorado Plateau. Sufficient outcrop and well control is currently available in the northwest and southeast portions of the San Juan Basin to indicate that the basement is somewhat more complex than previously considered (fig. 2). It should be pointed out that all outcrop and well control in Figure 2 penetrates the Precambrian.

The Precambrian varies from quartzite to schist and granite in the Four Corners region. However, the variations in Precambrian rock types and their relationship to the overlying Paleozoic sediments are beyond the scope of this paper. Comparison with relationships seen in the San Juan Mountains and Paradox basin suggests that the variations probably resulted from Late Precambrian tectonism.

Cambrian

Ignacio Formation

The Ignacio Formation was named by Cross, Howe and Ransome (1905) for exposures north of Rockwood, Colorado. The unit consists of quartzite, quartzose sandstone and friable sandstone with local shale lenses. Although the age of the Ignacio has been the subject of extensive discussion, it is now

considered to be Late Cambrian by most workers (fig. 1). The reader is referred to Barnes (1954), Baars and Knight (1957), Rhodes and Fisher (1957), Baars (1958) and Parker and Roberts (1963) for discussions concerning correlation problems, lithologic descriptions, evidence of age designations, faunal data and history of terminology.

The Ignacio Formation is considered to have been deposited by an eastward-transgressing sea; a thin blanket of sandstone of Late Cambrian age covered the Precambrian in the Four Corners region, extending to the San Juan Mountains of southwest Colorado where it is exposed in outcrops. The transgressive nature of the basal sandstone toward the east indicates that the region was slightly positive until Late Devonian time (Baars, 1958).

Although the eastward-transgressing Cambrian seas undoubtedly deposited thin sandstones in northwest New Mexico, the Ignacio is locally preserved only in relatively small, isolated blocks that appear to be fault-bounded (figs. 2 and 3). Here the Ignacio is restricted to down-thrown fault blocks and is flanked by rocks of younger age that nonconformably overlie the Precambrian. Deposition of Late Cambrian sandstone was not restricted to these grabens, but following post-depositional faulting and erosion of the Cambrian sediments from the structurally positive areas, only isolated remnants were preserved.

Devonian

Aneth Formation

The Aneth Formation was named by Knight and Cooper (1955) as the oldest recognizable Devonian strata of the Colorado Plateau. In the type locality it consists of up to 200 ft. of dark-colored, resinous limestone and argillaceous dolomite with intercalated black shale and dark siltstone. The Aneth conformably underlies the Elbert Formation and disconformably overlies the Late Cambrian elsewhere in the Four Corners (Baars and Campbell, 1968). The Aneth is restricted to the subsurface in extreme southeast Utah and northwest New Mexico and does not crop out in any known localities.

Parker and Roberts (1963) considered the Aneth to be the basal euxinic facies of the Elbert Formation, deposited in local sags or basins. These local sags may, in fact, be tectonically controlled and not entirely depositional as Parker and Roberts inferred. In Figure 2, notice the fault-controlled pattern of Aneth nonconformably overlying Precambrian rocks and its relationship to the Cambrian. A depositional history similar to that of the Ignacio is inferred, as indicated by the isolated fault-bounded occurrences. Figure 4 shows that slight tectonic movement appears to have been ongoing shortly before Aneth deposition, with renewed movement during or shortly after

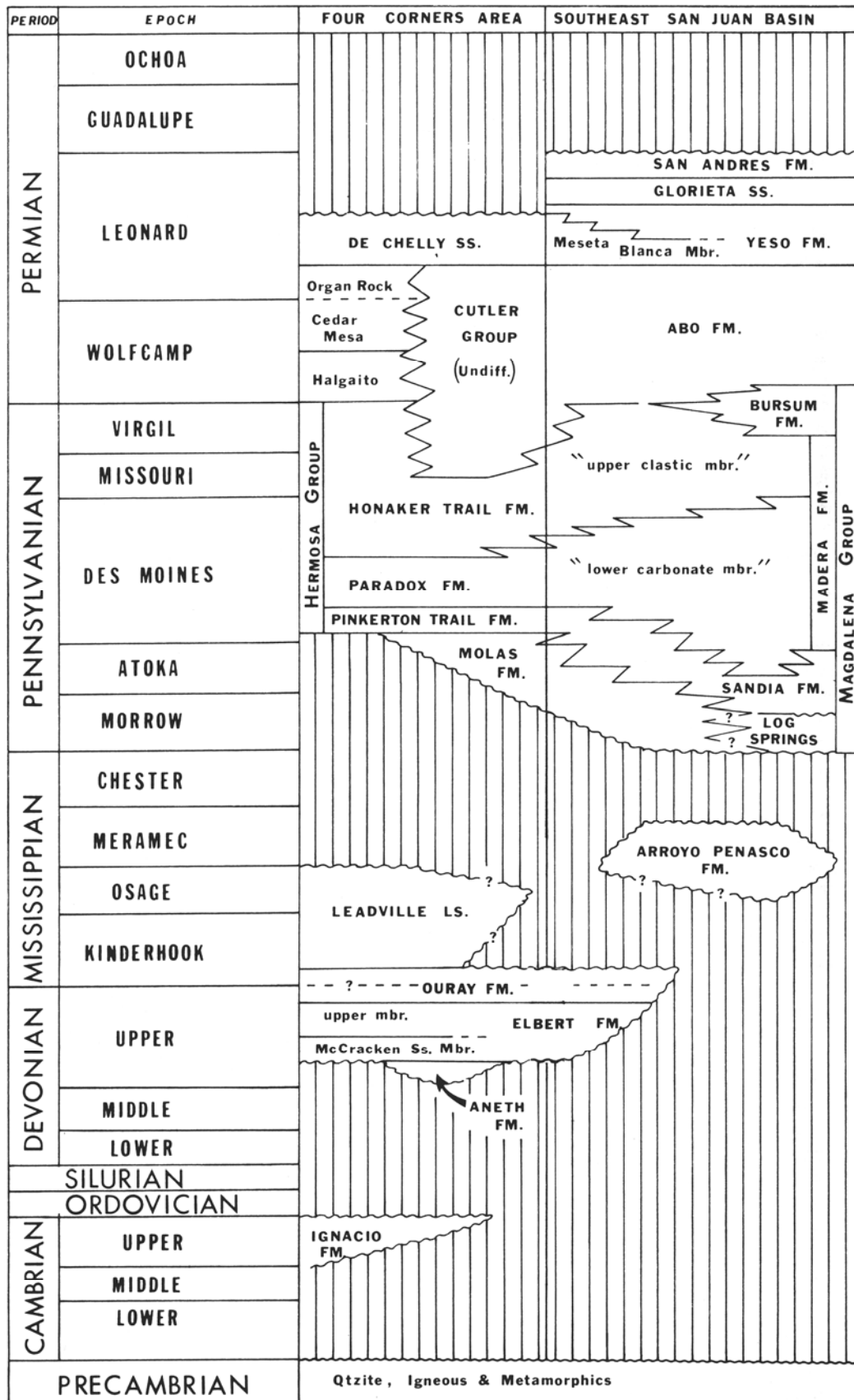


Figure 1. Paleozoic correlation chart of the San Juan Basin.

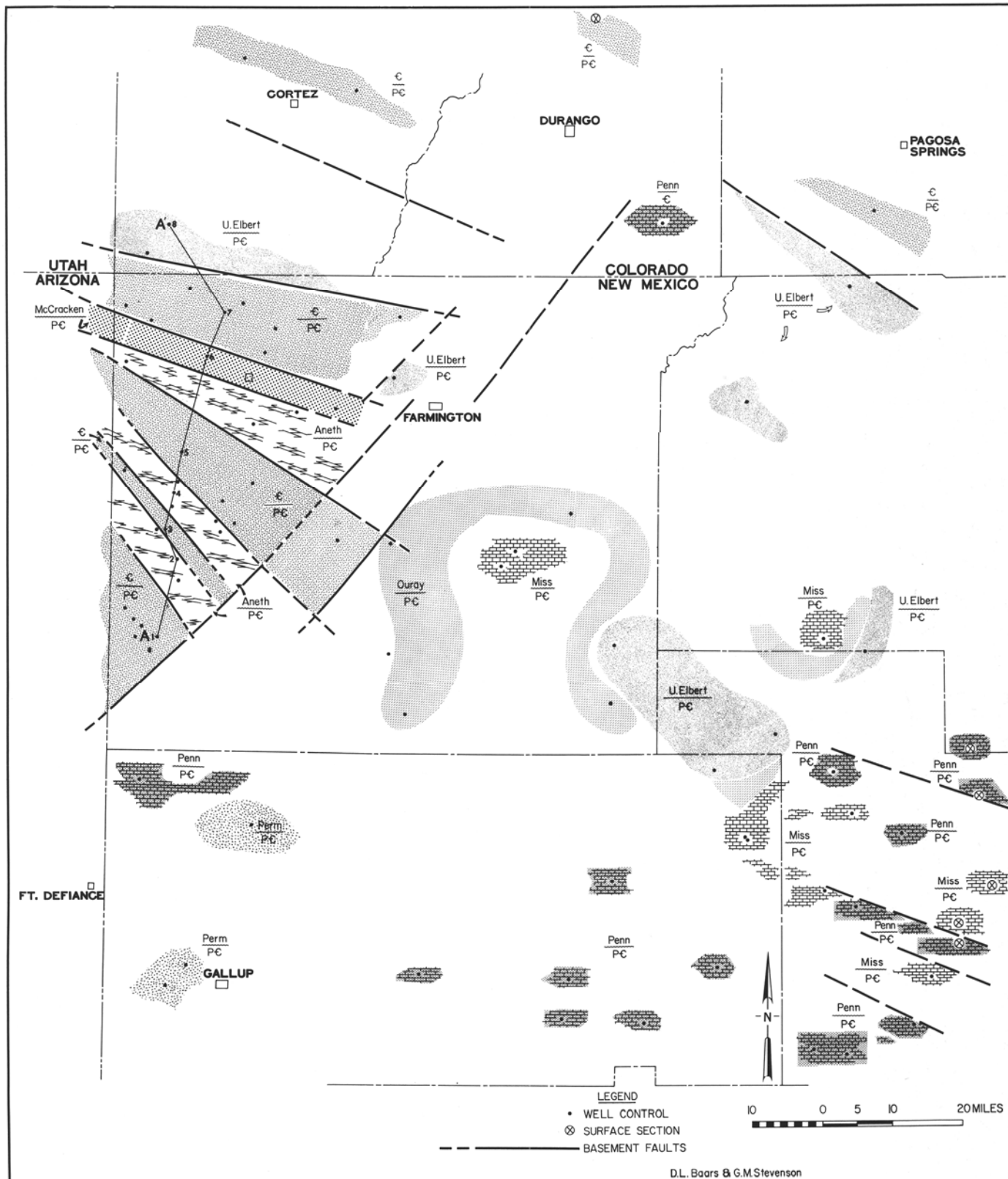


Figure 2. Worm's eye map showing nonconformable contact of Paleozoic sediments with Precambrian basement. All control points penetrate Precambrian.

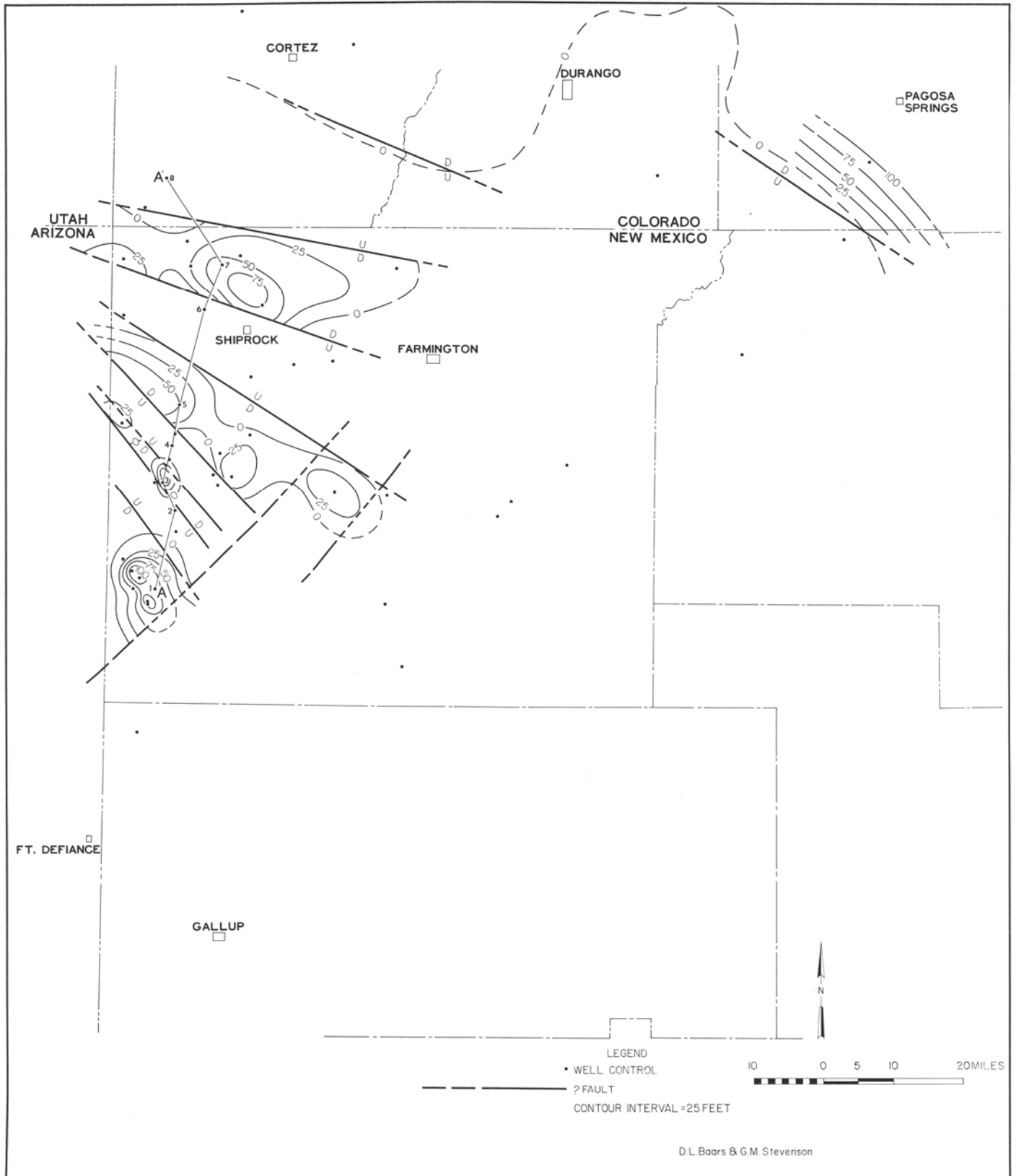


Figure 3. Isopach map of the Ignacio Formation.

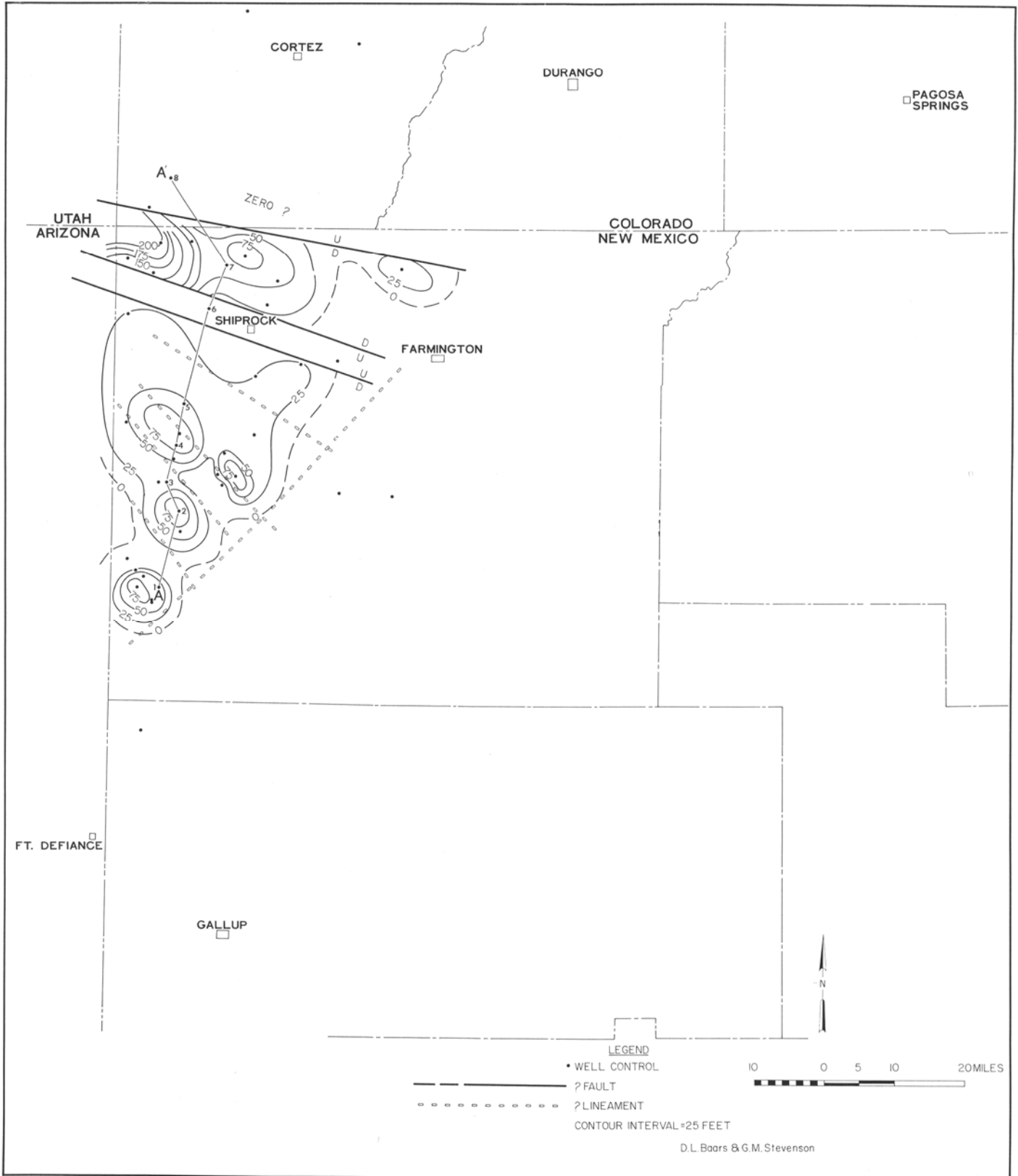


Figure 4. Isopach map of the Aneth Formation.

deposition. Fault blocks that were tensional (grabens) at Ignacio time were compressional (horsts) at Aneth time, and vice versa (fig. 5).

The age of the Aneth Formation is considered to be Late Devonian on the basis of fish remains recovered from cores in the type well in southeast Utah (Knight and Cooper, 1955; Parker and Roberts, 1963, 1966; Baars and Campbell, 1968).

Elbert Formation

The Elbert Formation was named by Cross (1904) for exposures along Elbert Creek north of Rockwood, Colorado. The Elbert Formation conformably overlies the Aneth in the Four Corners region, but disconformably overlies Late Cambrian rocks in most other areas. Knight and Cooper (1955) redefined the Elbert and divided it into two members; the basal McCracken Sandstone Member and an upper dolomite and shale member.

The McCracken Sandstone Member is a fine- to medium-grained, light-gray to red, poorly sorted, glauconitic sandstone containing thin stringers of sandy dolomite. The McCracken is present in the San Juan Mountains, disconformably overlying sandstones of the Cambrian Ignacio Formation (Baars and Knight, 1957) with which it was originally included by Cross, Howe and Ransome (1905). The McCracken grades westward into sandy dolomite and gradually becomes indistinguishable from the undifferentiated Elbert along the western Colorado Plateau (Baars and Campbell, 1968).

Lessertine (1965) noted that the source of McCracken sediments was to the east and that numerous facies changes between sandstone, shale and carbonate testify to repeatedly changing conditions of provenance. Baars and Campbell (1968) stated that the McCracken was best developed on the high flanks of paleostructures and graded to sandy dolomite between paleotectonic highs. The apparent structural complexity of northwest New Mexico, as shown in Figures 2 and 6, suggests that Baars and Campbell's (1968) hypothesis can be applied locally, thereby casting some doubt on Lessertine's suggestion of changing conditions of provenance. That the source of McCracken sediments lies to the east is not refuted, but rejuvenation of structural lineaments in northwest New Mexico could also have resulted in drastically changing sedimentation conditions in an area of probable shallow-marine-shelf conditions (fig. 6). There is currently insufficient well control to determine whether, in fact, all of the fractures shown in Figure 6 were active during deposition, but their proximity to isopachous thicks and/or thins is obvious.

The upper member of the Elbert Formation consists of green, waxy shale, thin-bedded limestone and dolomite that is commonly sandy, and white glauconitic sandstone. Baars (1966) suggested a tidal-flat environment of deposition on the basis of occurrence of salt casts and stromatolites in outcrops in the San Juan Mountains.

The southern limit of recognizable Elbert was not previously extended as far into the San Juan Basin as it is here mapped (fig. 7). However, sample descriptions and mechanical-log characteristics are analogous to those of typical Elbert facies of southwestern Colorado and are considered equivalent. The influence of structural lineaments is still very much apparent in the control of sedimentation of the upper Elbert (figs. 2 and 7). Baars and Campbell (1968) stated that the member overlies Precambrian quartzites with angular unconformity on fault blocks in the San Juan Mountains. Likewise,

the upper member nonconformably overlies the Precambrian in the extreme southwest corner of Colorado (figs. 5 and 7).

Fish fauna, identified as Late Devonian in age, have been found in the upper member of the Elbert in the San Juan Mountains (Baars and Campbell, 1968).

Ouray Formation

The Ouray Formation was named by Spencer (1900) for 100-200 ft. of massive limestone at Ouray, Colorado. The Ouray is a dark-brown limestone and dolomite that conformably overlies the Elbert Formation throughout the Colorado Plateau.

The Ouray, as here mapped, extends much farther into the San Juan Basin than it was previously mapped (fig. 8). Although no faults dissect the Ouray, the basement lineaments appear to have been reactivated to the extent of continuing to control or influence sedimentation (figs. 5 and 8).

The exact age of the Ouray has been the subject of debate in papers by Parker and Roberts (1963, 1966); Baars (1966), and Baars and Campbell (1968), to which the reader is referred for detailed discussion. Locally, the Ouray contains numerous brachiopods, gastropods, crinoids, rugose corals and foraminifera, indicating a marine origin and a generally low-energy environment (Baars, 1966).

The Ouray was considered to be of Late Devonian age because of its distinctive *Paurorhyncha endlichii* (Meek) and *Cyrtiopsis animasensis* (Girty) brachiopod fauna, until Knight and Baars (1957) suggested a possible Early Mississippian age of part of the Ouray, and Parker and Roberts (1963) reported evidence confirming a basal Mississippian age for the upper Ouray. Baars (1966) reported that cores from several wells in southeast Utah and southwest Colorado contain Kinderhookian (?) endothyrid Foraminifera from the top few feet of the formation. In the southern San Juan Basin, the Ouray could be early Kinderhookian in age, as it is overlain by the Arroyo Periasco Formation of Osage to Meramecian age. Conodonts of Devonian age have recently been found in the Ouray near Rockwood, Colorado.

As a compromise to all this confusion, the writers suggest that the formation is diachronous and representative of both geologic periods. The Ouray appears to be Late Devonian (Frasnian) in age in the type locality, and it progressively grades southward into younger rocks of Kinderhookian (?) age

Table 1. Control Used on Cross-Section A-A'

1. Kerr-McGee, #1-A Navajo, sec. 12, T. 23 N., R. 20 W., San Juan County, New Mexico.
2. Champlin, Navajo-Humble #1, sec. 16, T. 25 N., R. 19 W., San Juan County, New Mexico.
3. Humble, #1-D Navajo, sec. 30, T. 26 N., R. 19 W., San Juan County, New Mexico.
4. Texaco, #1-Navajo AS, sec. 28, T. 27 N., R. 19 W., San Juan County, New Mexico.
5. Amerada, #1 Navajo 32, sec. 27, T. 28 N., R. 19 W., San Juan County, New Mexico.
6. Sinclair, #1 Navajo 4000, sec. 12, T. 30 N., R. 19 W., San Juan County, New Mexico.
7. Humble, #1-C Navajo, sec. 8, T. 31 N., R. 18 W., San Juan County, New Mexico.
8. California Co., #1 Ute, sec. 22, T. 33 N., R. 19 W., Montezuma County, Colorado.

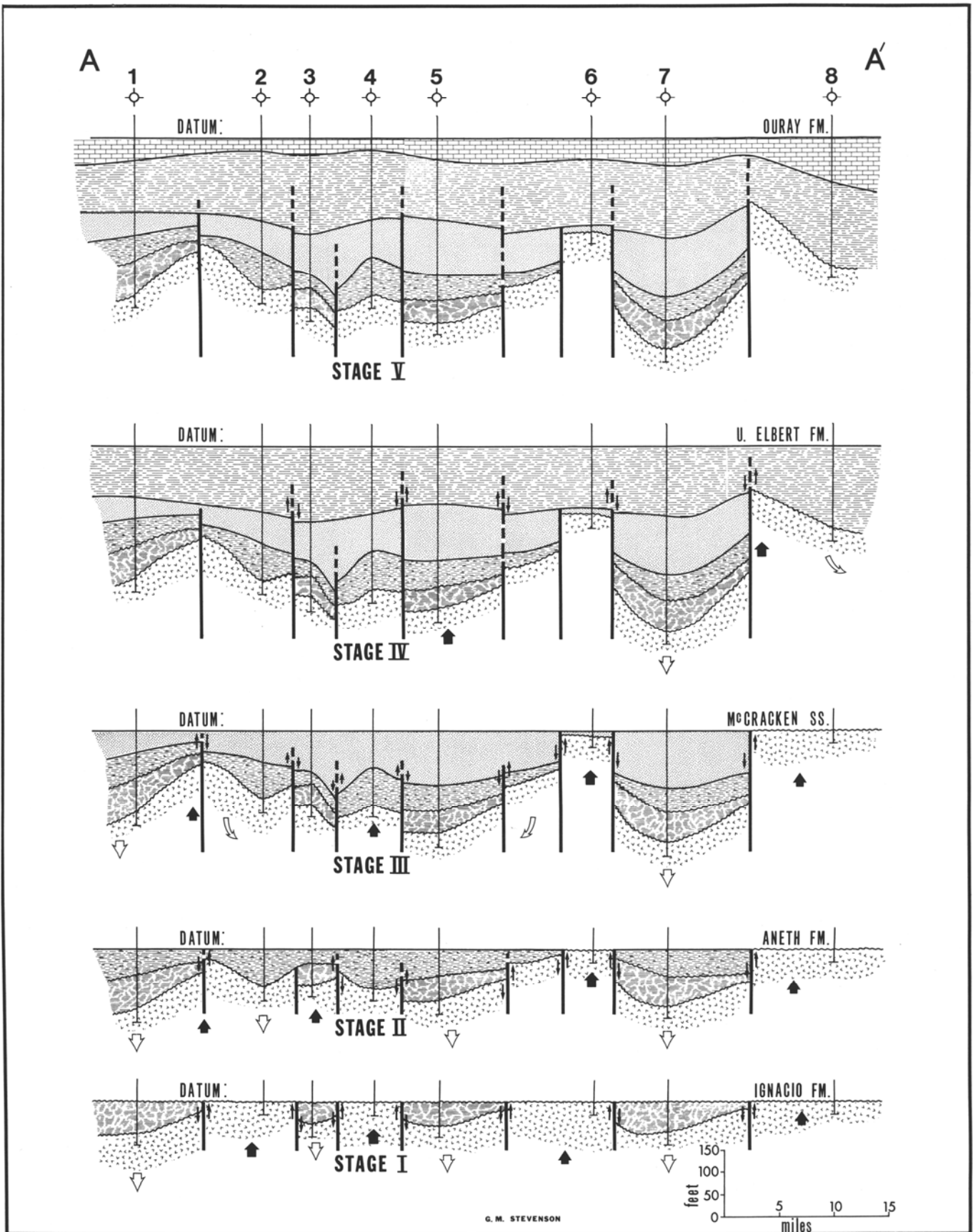


Figure 5. Cross section A-A'. See Table 1 for well names and locations.

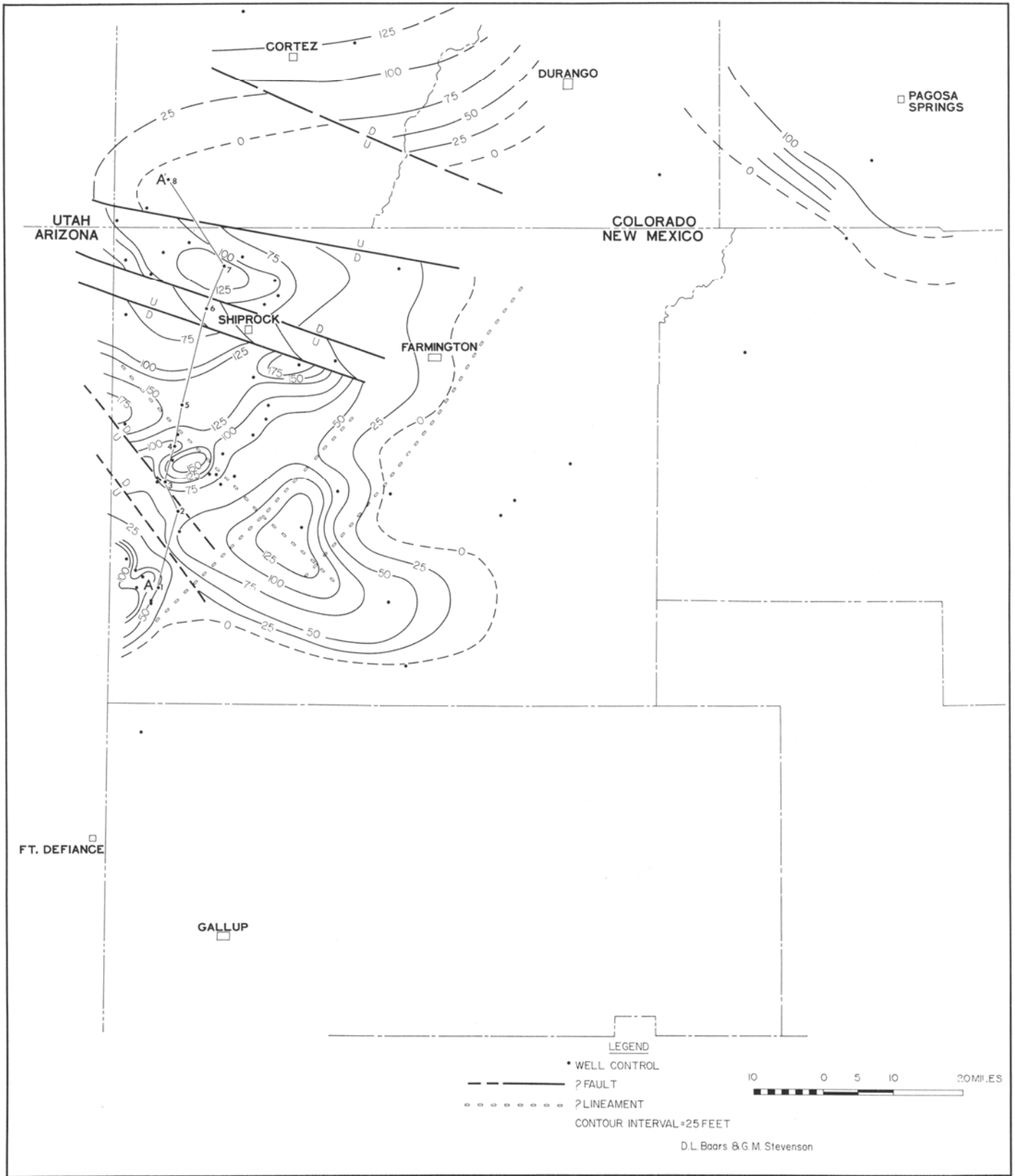


Figure 6. Isopach map of the McCracken Sandstone Member of the Elbert Formation.

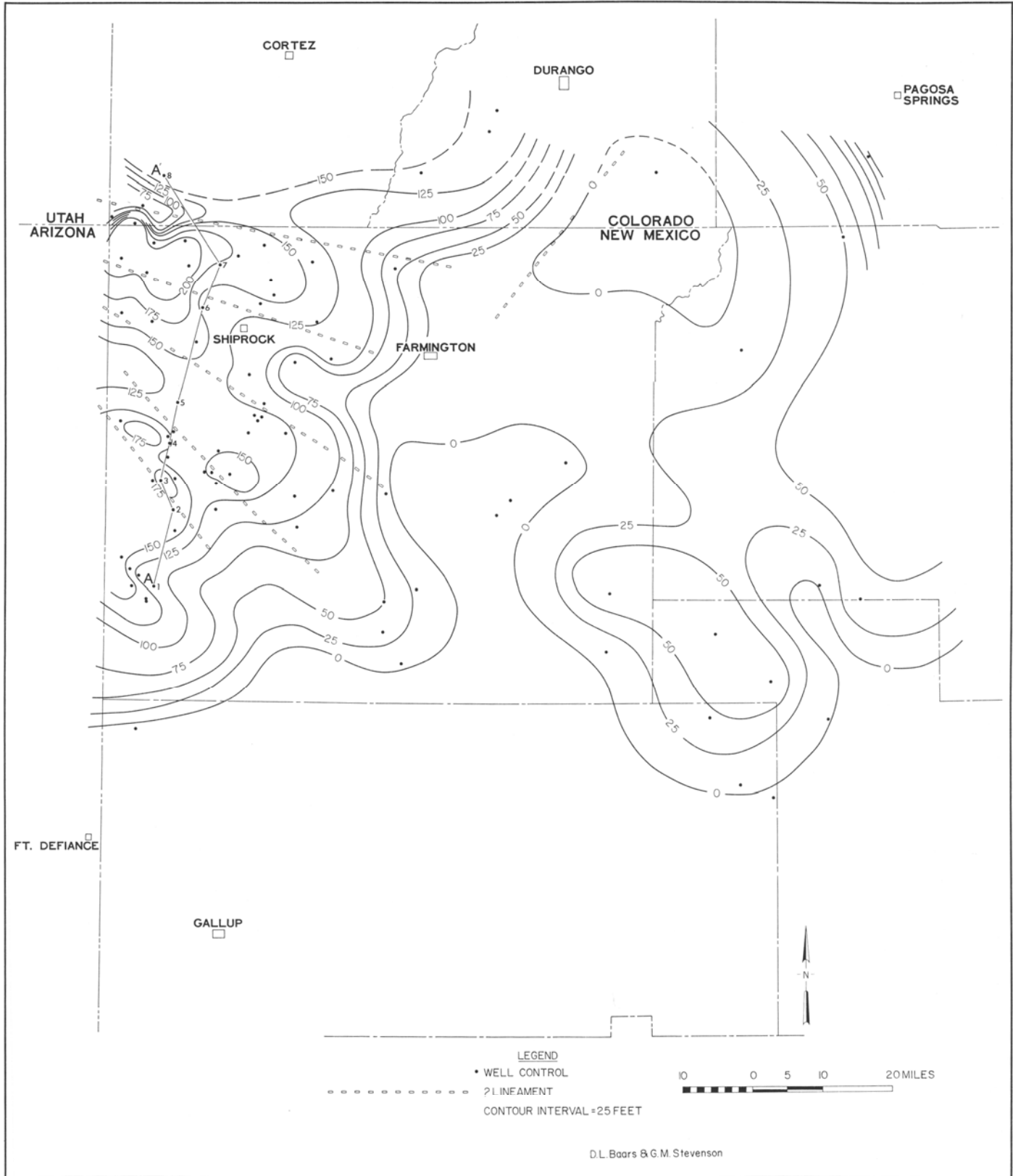


Figure 7. Isopach map of the upper member of the Elbert Formation.

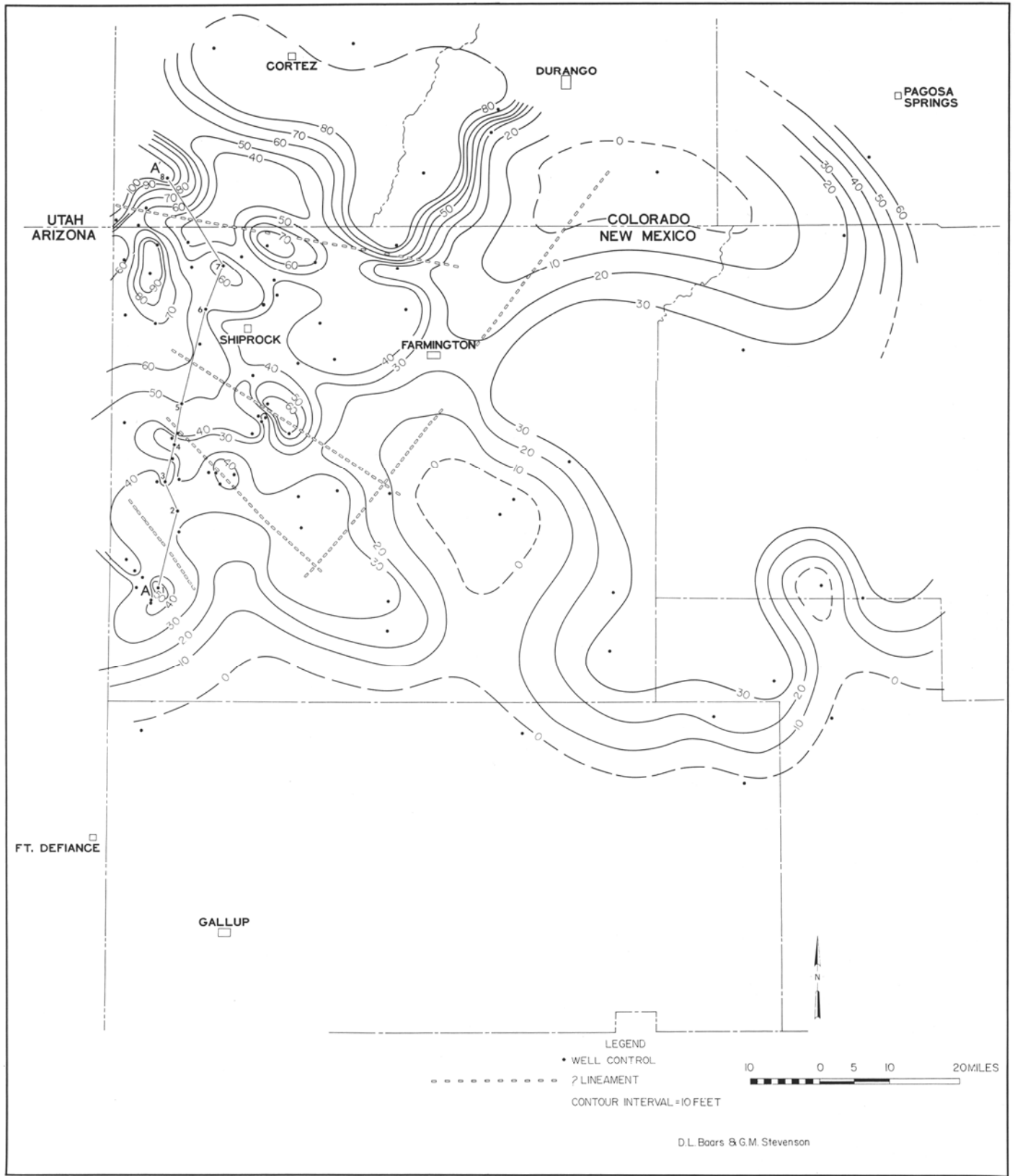


Figure 8. Isopach map of the Ouray Formation.

in the southern San Juan Basin. In any event, the writers have included the Ouray in the Devonian for purposes of mapping. In the Four Corners area, the Ouray is overlain with apparent conformity by the Kinderhookian to Osagian Leadville Limestone (Baars and Campbell, 1968).

PALEOTECTONICS

Baars (1966) demonstrated that a large northwest-trending graben consisting of Late Precambrian through Mississippian rocks is exposed in the core of the San Juan Mountains near Silverton, Colorado. It was shown that tectonism was rejuvenated periodically throughout the Paleozoic and that these structural lineaments actively controlled sedimentation through Mississippian time. Baars further extended these structural relationships into the subsurface of the eastern Paradox basin. This structure was shown to join a major northwest-trending pre-Pennsylvanian system of faults along each of the major salt anticlines. Baars (1972) further demonstrated a similar history for the Uncompahgre uplift.

Baars (1977) has recently shown that these structural lineaments of the Paradox basin and San Juan Mountains are closely related to a major system of northwest-trending lineaments extending from Vancouver Island, British Columbia, to the Ouachita Mountains of Oklahoma. Much of the evidence indicates that these lineaments have a Late Precambrian origin and that movement along them has recurred periodically.

With the ever increasing number of deep wells being drilled, a similar tectonic history is beginning to unfold in the Four Corners region. Although the magnitude of these lineaments is considerably less than for those shown by Baars (1966) in the Paradox basin; they have been paramount in controlling sedimentation in the San Juan Basin from Cambrian through Devonian time, and possibly throughout the entire Phanerozoic.

Tectonic lineaments were present by Late Cambrian time, controlling sedimentation in the northwestern San Juan Basin (fig. 3). The isolated remnants of the Ignacio Formation suggest that the topographic expression of the structures was well developed prior to deposition of Ignacio sediments (figs. 2, 3 and 5). Although precise dating on movement of these ancient fractures is unclear, a relative age of movement can be determined by stratigraphic sequence. Displacement could have begun during Late Precambrian time and extended into the Devonian until deposition of the Aneth Formation. However, the general lack of erosional effects at the top of the Ignacio suggests relative quiescence from Late Cambrian through Middle Devonian time, thereby suggesting that movement might actually have been syndepositional with the Ignacio.

Late Devonian rejuvenation of the ancient fractures occurred prior to deposition of the Aneth Formation, as shown in Stage II in Figure 5. The resulting down-thrown fault blocks were not entirely the same as those at Ignacio time; that is, what appeared as Cambrian horst blocks (Stage I) were grabens by Aneth time (Stage II, fig. 5; also figs. 2 and 4). This oscillatory movement of the fracture system apparently continued through the close of the Devonian, as isopachous trends in the McCracken, upper member of the Elbert, and Ouray reflect the influence these structures had on controlling sedimentation, at least locally, in northwest New Mexico (figs. 6, 7 and 8).

PETROLEUM OCCURRENCES

Although rocks of Cambrian and Devonian age have yielded only slight amounts of oil and gas in the San Juan Basin, the production is apparently related to these ancient structural features. A delicate paleotectonic balance controlled reservoir development along these fractures. Potential reservoirs may have been removed by erosion if the structural relief became too great, either during or shortly after deposition. Apparently, the only fault block that withstood this delicate balance of structure and sedimentation was in the Beautiful Mountain area. Here, the Akah Nez field has produced 17,199 BO from the McCracken and Ignacio (?). Several wells in the near vicinity had favorable drill stem tests but were plugged, probably due to unfavorable economic conditions. In the future, geologists exploring in the San Juan Basin for early Paleozoic hydrocarbon reservoirs should make every effort to reconstruct the paleotectonic history of the area as it relates to the control of lithofacies and reservoir development. One must go back to the original depositional basin to understand oil occurrences.

CONCLUSIONS

Structural and stratigraphic relations of Cambrian and Devonian strata in the northwest portion of the San Juan Basin suggest that this area has had a long history of tectonism and that the Four Corners platform may not have always been as stable as has been previously conjectured.

Sufficient well control is currently available in the northwest corner of New Mexico to suggest that basement structures were episodically active throughout the lower Paleozoic and were responsible for controlling sedimentation. Once these paleotectonic features are understood, they can be compared to other less understood areas in the central San Juan Basin.

A discussion of the mechanics of these structures is beyond the scope and physical limitations of this paper, but will be forthcoming in the near future. However, some interesting observations can be made at this time:

- (1) Block faulting of the basement appears to be present in the northwest and southeast portions of the San Juan Basin; these are not simple tensional features because individual fault blocks can be shown to oscillate through time from tensional normal faults to compressional reverse faults and back to normal faults (fig. 5).
- (2) The magnitude of vertical displacement along these faults is small, but sufficient to control sedimentation (figs. 3, 4, 6, 7 and 8).
- (3) Because of the minor amount of vertical movement that is apparent, it would be more descriptive perhaps, to refer to these structures as "fractures" or "megafractures."
- (4) The apparent northwest-southeast trend of lineaments suggests a close relationship to the larger Uncompahgre tectonism which originated in the Precambrian (Baars, 1966).
- (5) The northwest-trending lineations of the fractures in the northwest and southeast San Juan Basin strongly suggest that similar lineations are present in the central San Juan Basin, but stratigraphic control is so sparse that, at present, they are only conjectural.
- (6) The alternating up-and-down "yo-yo tectonics" (fig. 5) are typical criteria for wrench or strike-slip faulting. Baars (1977) has demonstrated how large-scale hori-

zontal compressional forces can create local vertical tensional features in the Colorado Plateau.

REFERENCES

- Baars, D. L., 1958, Cambrian stratigraphy of the Paradox basin region: Intermtn. Assoc. Petroleum Geologists, 9th Ann. Field Conf. Guidebook, p.93-101.
- 1966, Pre-Pennsylvanian paleotectonics-Key to basin evolution and petroleum occurrences in Paradox basin, Utah and Colorado: Am. Assoc. Petroleum Geologists Bull., v. 50, no. 10, p. 2082-2111.
- 1972, Pre-Pennsylvanian paleotectonic framework of Ancestral Rockies of Colorado [abs.] : Colo. School Mines Quart., v. 67, no. 4, p.137.
- 1977, The Colorado Plateau aulogogen-Key to continental scale basement rifting: 2nd International Conf. on the New Basement Tectonics Proc. (in press).
- Baars, D. L., and Knight, R. L., 1957, Pre-Pennsylvanian stratigraphy of the San Juan Mountains and Four Corners area: New Mexico Geol. Soc. Guidebook, 8th Field Conf., p. 108-131.
- Baars, D. L., and Campbell, J. A., 1968, Devonian System of Colorado, northern New Mexico and the Colorado Plateau: Rocky Mtn. Assoc. Geologists, v. 5, p. 31-40.
- Barnes, Harley, 1954, Ignacio quartzite in southwestern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1780-1791.
- Cross, Whitman, 1904, A new Devonian formation in Colorado: Am. Jour. Sci., 4th Ser., v. 18, p. 245-252.
- Cross, Whitman, Howe, Ernest and Ransome, F. L., 1905, Silverton, Colorado: U.S. Geol. Survey Folio 120.
- Knight, R. L., and Baars, D. L., 1957, New developments on age and extent of Ouray limestone [Colorado Plateau] : Am. Assoc. Petroleum Geologists Bull., v. 41, no. 10, p. 2275-2283.
- Knight, R. L., and Cooper, J. C., 1955, Suggested changes in Devonian terminology of the Four Corners area: Four Corners Geol. Soc., 1st Ann. Field Conf. Guidebook, p. 56-58.
- Lessentine, R. H., 1965, Kaiparowits and Black Mesa basins-Stratigraphic synthesis: Am. Assoc. Petroleum Geologists Bull., v. 49, no. 11, p.1997-2019.
- Parker, J. W. and Roberts, J. W., 1963, Devonian and Mississippian stratigraphy of the central part of the Colorado Plateau, *in* Shelf Carbonates of the Paradox Basin-Symposium: Four Corners Geol. Soc., 4th Ann. Field Conf. Guidebook, p. 31-60.
- 1966, Regional Devonian and Mississippian stratigraphy, central Colorado Plateau: Am. Assoc. Petroleum Geologists Bull., v. 50, no. 11, p. 2404-2433.
- Rhodes, F. H. T., and Fisher, J. H., 1957, Ignacio quartzite of southwestern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 2508-2518.
- Spencer, A. C., 1900, Devonian strata in Colorado: Am. Jour. Sci., 4th Ser., v. 9, p. 125-133.