LOWER CRETACEOUS ROCKS OF NORTHWESTERN COLORADO AND NORTHEASTERN UTAH

by
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ABSTRACT

Lower Cretaceous rocks of northwestern Colorado and northeastern Utah consist of three distinct units — the Cedar Mountain Formation, Dakota Sandstone and Mowry Shale. Because they represent deposits laid down before and during the westward transgression of the Mancos sea, it is possible to recognize in them sediments formed in various subdivisions of the floodplain, paludal, lagoonal-estuarine, littoral marine and neritic environments.

In this region commercial accumulations of petroleum have been encountered in at least 51 fields but production has been small, totalling 14.6 million barrels of oil and 164.8 billion cubic feet of gas. Most of this production has come from floodplain and paludal channel sandstones of the Cedar Mountain and Dakota, but some has come from littoral sandstones and fractures in neritic shales. New discoveries await deeper exploratory tests within the Uinta, Piceance Creek and Sand Wash Basins.

INTRODUCTION

Lower Cretaceous rocks are present throughout most of northwestern Colorado and northeastern Utah, but exposures are limited to narrow outcrops on the flanks of the Uinta Mountains and a portion of the margins of the Sand Wash, Piceance Creek and Uinta basins. Knowledge of the deeper portions of the basins is largely restricted to data from petroleum tests clustered near basin margins.

The earliest geological investigations in this region were federal government surveys under the direction of Clarence King (1871-78) and F. V. Hayden (1870's and 1880's). Geologists of these surveys noted the presence of Lower Cretaceous strata and included them in the "Dakota Group" and the basal part of the "Middle Cretaceous" or "Colorado Group". In some areas the lowermost beds were included in the underlying "Jurassic". Since that time these rocks have been studied by various researchers who have defined their upper and lower boundaries, identified the contained fossils, postulated environments of deposition and recorded their salient physical characteristics. The most pertinent contributions to the stratigraphy of these rocks are those by Konishi (1959), Lane (1963), Munger (1965), O'Boyle (1955), Quigley (1959), Sharp (1964) and Young (1960).

Early reports list numerous gas and oil seeps in this region but none were recorded in Lower Cretaceous rocks. As a consequence, these strata were not thought of as potential producing units until 1924 when the Texas Company found oil in the Dakota Sandstone on Moffat (Hamilton) dome and Midwest Oil Company discovered oil in the Mowry Shale at Iles dome. These Colorado finds were followed by the discovery of oil and gas in the Dakota Sandstone and Cedar Mountain Formation at Cisco dome in Utah in 1925. As of November 1, 1974, petroleum had been encountered in commercial amounts in Lower Cretaceous rocks in at least 51 fields in this region (Table 1 and Fig. 1). In addition, some production attributed to the Morrison Formation has actually been from Lower Cretaceous rocks, but even with this contribution total Lower Cretaceous production has been relatively small.

The purpose of this report is to summarize the pertinent lithologic characteristics of the Lower Cretaceous units, to

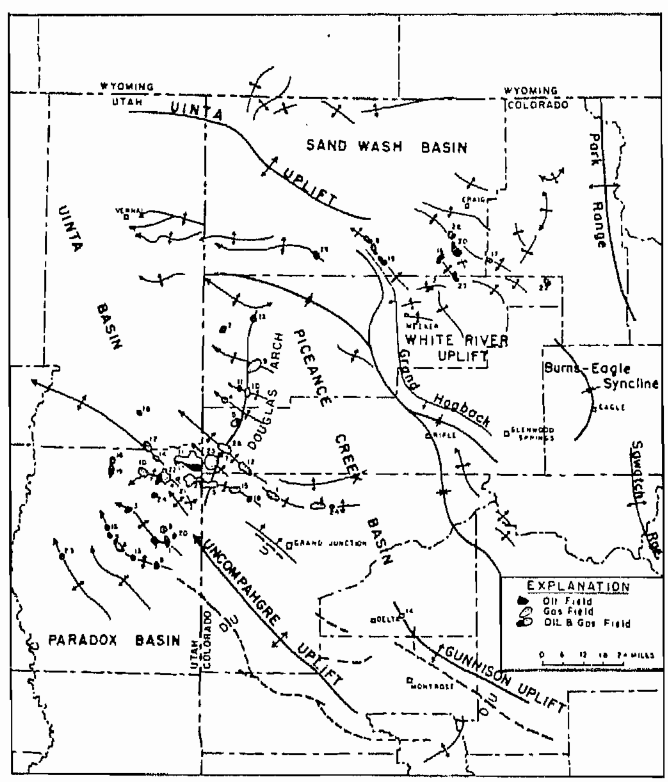

Fig. 1 — Oil and gas fields with production from Lower Cretaceous rocks.

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TABLE I.—Lower Cretaceous Oil and Gas Producing Fields

COLORADO (as of 1/1/75)

FIELD	PROD. UNIT	BBLS OIL	MCF GAS
1. Asbury Creek (Storage)	Kd	— [a]	2,406,841
2 Banta Ridge	Kd	757	3,378
3. Bar X	Kd-Jm	—	3,573,514
4. Baxter Pass (S.I.)	Kcm-Jm	—	—
5 Baxter Pass South (S.I.)	Kcm-Jm	—	—
6 Cameo	Kd	—	29,238
7. Carbonera	Kd-Kcm	121	846,286
8 Danforth Hills	Kd	251,719	88,903
9. Douglas Creek	Kd	—	8,456,364
10. Douglas Creek South	Kcm-Jm	—	18,837
11. Foundation Creek	Kcm	5,127	47,213
12 Gar Mesa	Kd-Jm	—	3,721,693
13. Gilliam Draw	Kd	—	84,718
14. Happy Hollow (CO_2 – S.I.)	Kd	—	—
15. Highline Canal (Storage)	Kd-Jm	—	273,000
16 Iles (Abn.)	Mowry	147,470	—
17 Indian Run (S.I.)	Kd	—	—
18. Mack Creek (Abn.)	Kcm	—	13,171
19. Maudlin Gulch	Kd	3,821,277	739,915
20. Moffat	Km-Kd-Jm-Js-Ћcs	8,291,296	80,081
21. Nine Mile	Kd	799,309	—
22 Pinnacle (Abn.)	Kd	108,943	71,629
23. Prairie Canyon	Kd-Jm	—	1,718,868
24 Roberts Canyon	Kd	—	375,773
25. South Canyon	Kd-Kcm	—	7,144,423
26. Texas Mountain	Kd	—	656,744
27. Thornburg (Abn.)	Kd	—	4,059,822
28. Williams Fork	Kd	724,291	30,326
29. Winter Valley	Kd	274,405	12,774,634
	TOTALS	14,424,715	47,312,371

UTAH (as of 11/1/74)

FIELD	PROD. UNIT	BBLS. OIL	MCF GAS
1. Agate	Kcm	18,976	79,680
2 Bar X	Kd-Kcm-Jm	—	14,295,336
3. Book Cliff	Kd-Kcm	—	269,278
4. Bryson Canyon	Kd-Kcm-Jm	—	7,677,976
5. Bull Canyon	Kd	10,561	—
6. Cisco Dome (Abn.)	Kd-Kcm-Jm	—	2,675,277
7 Cisco Springs	Kd	4,306	47,624
8. Cisco Townsite (Abn.)	Kcm	1,457	—
9 Danish Wash	Kd	—	51,329
10. Diamond Ridge	Kcm-Jm	—	261,455
11. East Canyon	Kd-Kcm-Jm	3,028	4,162,728
12 Fence Canyon	Kd	—	472,746
13. Gravel Pile	Kcm	1,845	26,997
14 Horse Point	Kd	—	1,037,689
15. Left Hand Canyon	Kd	18,272	—
16. Moon Ridge	Kcm	—	1,084,921
17. San Arroyo	Km-Kd-Kcm-Jm	96,684	59,010,485
18. Seep Ridge	Kd	—	—
19. Segundo Canyon	Kcm	704	771,247
20 Sieber Nose	Kcm	15,188	—
21. State Line	Kd	—	1,196,731
22. Westwater	Kd-Kcm-Jm	10,082	24,427,448
23. NW Salt Valley Anticline	Kd	—	—
24. Pear Park	Kd	—	—
	TOTALS	181,103	117,548,947

relate these features to depositional environments and to review past and present exploration concepts in the search for petroleum in this region.

GEOLOGIC HISTORY

Lower Cretaceous rocks of this region document an important sequence of events in regional history. Evidence obtained from this and adjacent regions indicates that in early Aptian time the ancient Mesozoic trough in western Utah and eastern Nevada was deformed into the Sevier orogenic belt. As this belt became more positive, a broad area to the east began to subside to form the Rocky Mountain geosyncline. Innumerable braided streams carried vast quantities of coarse clastics from the rising orogenic belt into the subsiding trough to the east. At least three major episodes of braided stream deposition, probably resulting from strong orogenic movements in the Sevier belt, can be recognized. Each flood of coarse debris was followed by a period of less active erosion during which a smaller number of streams meandered across the extensive floodplains and finer clastics accumulated in interchannel areas.

There followed a period of erosion which terminated near the beginning of Albian time with renewed activity in the orogenic belt and simultaneous downwarping of the geosyncline. A fourth flood of coarse clastics swept eastward and northeastward where it encountered a shallow sea creeping into the trough from both north and south. With the arrival of this sea there was now a whole new suite of depositional environments (including neritic, littoral-deltaic, lagoonal-estuarine and paludal) occupying a large part of the area formerly covered by subenvironments of the floodplain.

With continued subsidence in the geosyncline the boreal and austral seas merged and began to spread to the east and west. This expansion caused bordering transitional environments to shift landward at the expense of the rapidly shrinking floodplain. This invading sea approached northwestern Colorado from the northeast, arriving just prior to the end of the Albian. However, as it neared this area large scale volcanic activity in the source area generated great volumes of ash which on reaching the sea in western Wyoming was spread south and east by marine currents to form highly siliceous neritic muds.

STRATIGRAPHY

Lower Cretaceous rocks of this region can be subdivided into three stratigraphic units. Two of these — the Cedar Mountain Formation and the Dakota Sandstone — comprise the Dakota Group and are present throughout most of the study area. The Mowry Shale, a subdivision of the Mancos Shale, is the marine equivalent of the upper part of the Dakota Sandstone. It is present in all but the southwestern portion of the region. Figure 2 shows the thickness of these rocks and the distribution of the Mowry Shale.

Cedar Mountain Formation

The lowermost Cretaceous unit throughout most of the study area is the Cedar Mountain Formation. In most places it consists of a basal light gray to light brown con-

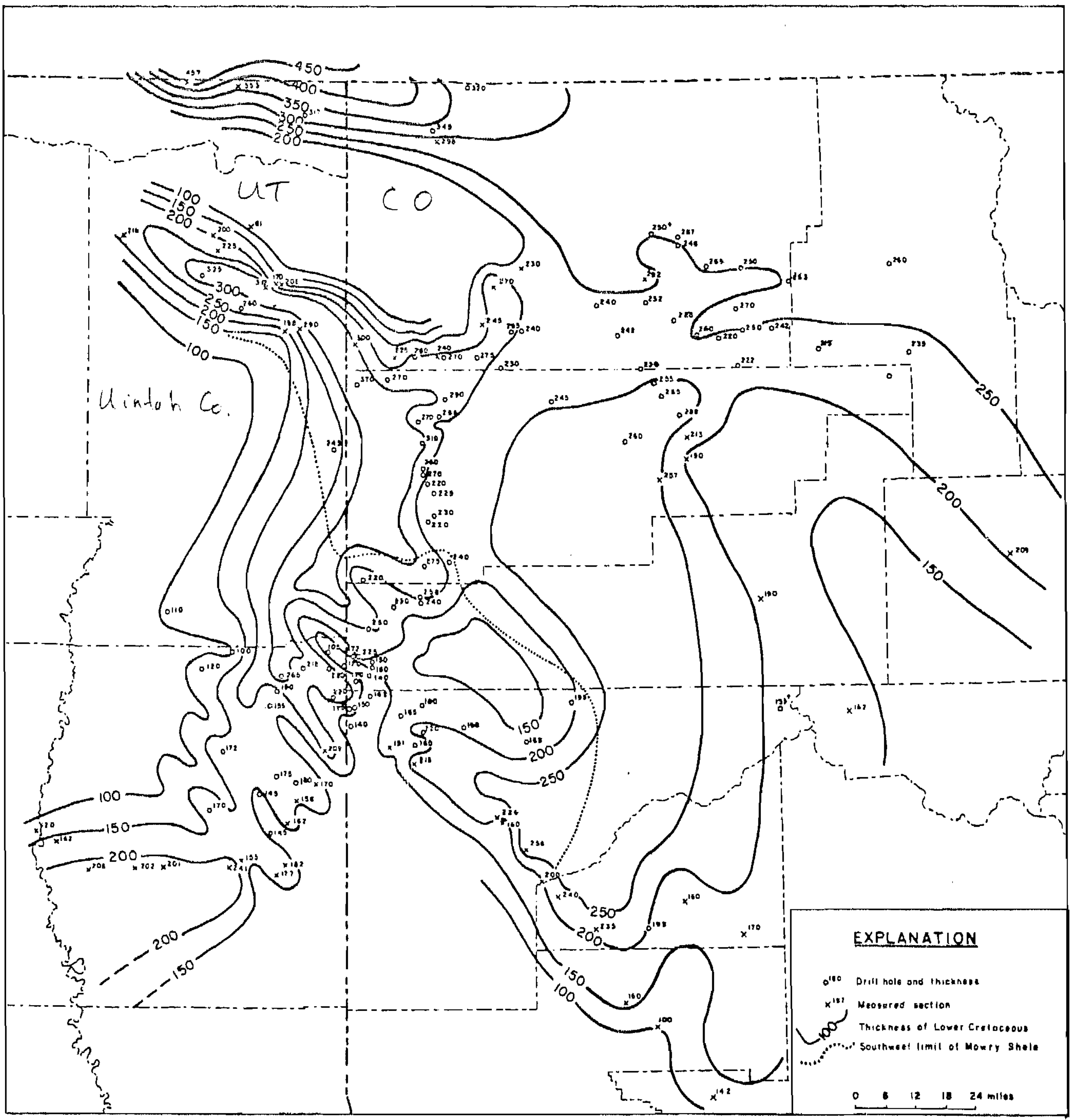

Fig. 2 — Isopach of Lower Cretaceous rocks.

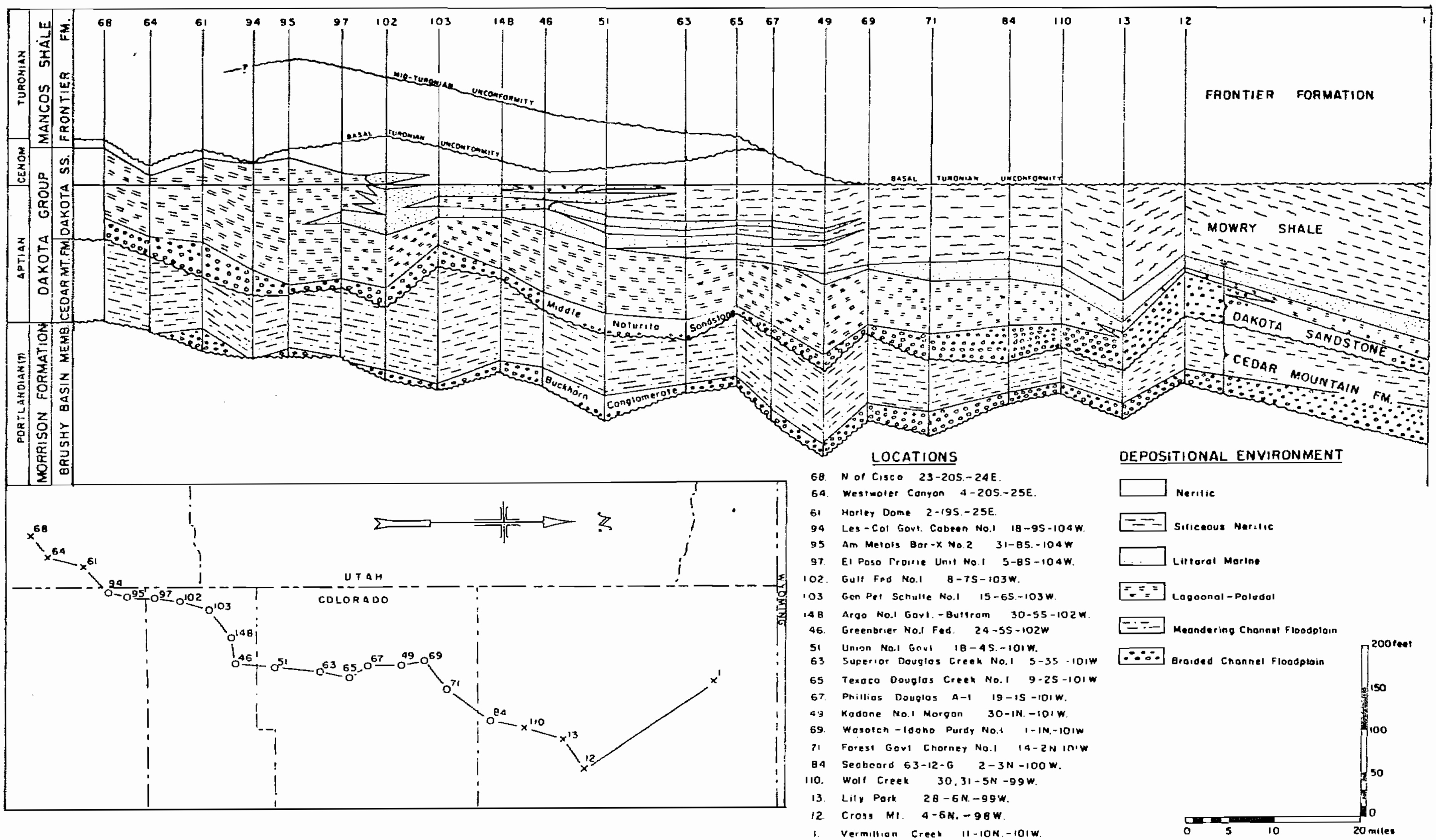

Fig. 3 — Correlation of Lower Cretaceous units from southern Uinta basin to Sand Wash basin.

glomerate or conglomeratic sandstone and an overlying red to green to gray slightly bentonitic mudstone unit. Because the initial deposits of this unit were laid down upon a stream-dissected surface of Jurassic Morrison mudstone, the basal sandstone is present in paleovalleys but may thin or pinch out in old interfluve areas. Some of the deeper paleovalleys may contain two superimposed massive conglomeratic sandstone units — each totalling as much as 30 feet in thickness as shown in Figure 3. The conglomeratic sandstones, products of braided stream channels, are composed of innumerable overlapping lenses of moderately well sorted, calcite-cemented sand exhibiting moderately steep planar and trough type cross bedding. Scattered pebbles of chert and quartzite ranging up to two inches in diameter are present in most exposures. The fact that these sandstones are widely traceable is an indication of their blanket-like nature. The mudstone which normally separates the conglomeratic sandstones and constitutes the upper part of the formation is normally red but has been partly bleached to purple, green or gray beneath most sandstones. Included in it in many places are thin lenses of sandstone, siltstone and impure limestone. Also common are scattered nodules of siliceous limestone and varicolored gastroliths. Highly carbonaceous mudstone layers are present in some of the easternmost outcrops.

In this region the Cedar Mountain ranges up to 150 feet in thickness but averages about 100 feet. It rests disconformably on mudstones or channel-fill sandstones of the Morrison Formation and in most places is overlain with pronounced disconformity by the prominent Middle Naturita Sandstone of the Dakota Sandstone. In the southeastern portion of the region, where carbonaceous mudstone appears below the Middle Naturita Sandstone, the formational boundary shifts downward to the base of the next lower persistent conglomeratic sandstone (Lower Naturita or Upper Cedar Mountain Sandstone).

Diagnostic fossils are rare in this formation but it has yielded freshwater gastropods, pelecypods and ostracodes as well as caraphytes, leaves and dinosaur remains. On the basis of such evidence it is considered to be of Aptian age.

The writer (Young, 1973) has concluded that the blanket-like massive sandstones of this formation resulted from periodic episodes of deposition by a vast system of northeastward and eastward flowing braided streams carrying coarse clastics derived from a source in the Sevier orogenic belt. Most of the finer erosional products were apparently transported completely across the braided channel floodplain subenvironment and on to the distant sea. Where the braided streams encountered growing structures, such as the northwestward projection of the Uncompahgre uplift and the Douglas arch, they became confined to narrow valleys and the resulting deposits did not cover the higher parts of the interstream areas. Most of the valleys cut into these old highs are a few hundred feet to a mile wide and trend northeasterly. The channel-fill sandstones formed in these valleys have been productive where draped over structural highs.

The relatively thick units of mudstone, with their lesser lenses of sandstone and limestone, represent sediments deposited in meandering stream channel or interchannel subenvironments of the floodplain during relatively quiet periods between episodes of basinal subsidence and/or source area uplift.

Dakota Sandstone

The upper unit of the Dakota Group is the Dakota Sandstone of most authors (Young, 1960, used the name Naturita Formation on the Colorado Plateau). In most localities it is about 100 feet thick and consists of three lithologically distinct units: a lower widely traceable, brown weathering conglomeratic sandstone; a middle unit of carbonaceous shale and mudstone with some coal; and an upper unit of one or more fine- to medium-grained sandstones. The basal unit is merely a continuation of the braided channel subenvironment into the lowlands nearer the sea; consequently, it has most of the characteristics of the Cedar Mountain braided channel sandstones. However, many of the chert pebbles have been kaolinized and it contains much more plant debris and pyrite.

The middle unit generally consists of slightly to very carbonaceous mudstone and shale along with some low rank coal and an occasional lens of sandstone or siltstone. Studies of this unit have identified sediments of meandering channel, interchannel and coal swamp divisions of the paludal environment and salt marsh, tidal channel, tidal flat, tidal delta and lagoon pond subdivisions of the lagoonal-estuarine environment. Identifying characteristics of each of these subenvironments are discussed by Young (1973).

The upper unit is absent in some localities but where present it consists of one or more beds of tightly cemented, well sorted fine- to medium-grained quartzose sandstone commonly separated by thin beds of carbonaceous or slightly calcareous shale or mudstone. The sandstones generally intertongue with and grade eastward into the marine Mancos or Mowry shales. Most of these sandstone sheets are of littoral marine origin and represent mainland beach, barrier beach or delta front bar accumulations. They may be up to 15 feet thick, as much as a mile wide and parallel the old northwest-trending strandlines for many miles. In their landward portions they rest disconformably on lagoonal-estuarine-paludal rocks, but farther seaward their bases become gradational into underlying thin westward pointing tongues of marine shale. Their upper surfaces are generally minor surfaces of erosion over which the sea advanced, hesitatingly, westward.

Fossils are also sparse in the Dakota Sandstone, but scattered occurrences in the upper littoral unit and the partially equivalent Mowry Shale indicate that it is of Albian age in most of the region but becomes progressively younger toward the west by intertonguing with the Upper Cretaceous Frontier Formation. Near the Colorado-Utah border the uppermost part is of Late Cretaceous age as shown in Figure 3.

Mowry Shale

Throughout much of this area a relatively thin unit (0-160 feet) with distinctive electric log characteristics is present at or near the base of the Mancos Shale. This is the Mowry Shale, a hard, siliceous, silver-gray weathering, fissile neritic shale which on fresh exposure ranges from dark gray to dark brown. Sharp (1964) divided the formation into three units: a lower sandy to silty non-siliceous shale; a middle fish scale-bearing siliceous shale; and an upper relatively weak shale with minor sandstone interbeds. Bentonites up to six feet thick are common.

The bentonites and general high silica content indicate that a large volume of volcanic ash was contributed to the Mancos sea by volcanoes, probably located in southern Idaho and adjacent areas. These fine pyroclastics were transported eastward to the sea and then southeastward by longshore currents in the shallow sea.

The Mowry contains numerous fossils, among which are fish bones and scales, pelecypods and cephalopods. The latter include guide fossils for the middle and late Albian. In most places its top coincides with the boundary between Lower and Upper Cretacous rocks, and it is overlain by Cenomanian strata. However, in the western part of the area the Mowry is truncated by a middle Turonian unconformity.

STRUCTURE

The major structural features of this area are shown in Figure 1. Most of them owe their present structural relief to Laramide and post-Laramide deformations but some have their origins in much earlier episodes of crustal unrest. It is generally agreed that the location and general configuration of many of these features were predetermined by structure patterns inherited from the Precambrian. Such structures have been periodically reactivated in subsequent ages as temporarily positive or negative areas, or as zones of displacement.

At the end of Late Jurassic time this region appears to have been nearly featureless, structurally. Isopachs of nonmarine Late Jurassic sediments indicate this was a broad shelf or foreland area over which sediments were spread quite uniformly. However, the Lower Cretaceous isopach (Fig. 2) suggests that some structural features had begun to manifest themselves by that time. Most notable of these were the Gunnison and Uncompahgre uplifts and the Douglas Creek arch, a series of en echelon northwest trending subsidiary anticlines believed to be a northern extension of the Uncompahgre. At the same time there must have been some downwarping of the adjacent portions of the Uinta and Piceance Creek basins. Evidences for these movements are thinning of the Dakota Group, thickening of channel-fill sandstones in nonmarine deposits, and development of shoal sands in the marine Mancos Shale over the crest of the arch. It is possible that other structures in this region had begun to form by Early Cretaceous time (such as Thornburg and Iles domes), but present evidence is inconclusive.

ECONOMIC GEOLOGY

As noted previously, Lower Cretaceous rocks have not been prolific producers of oil and gas in this region. As of the end of 1974, a total of about 164.8 billion cubic feet of gas and 14.6 million barrels of oil had been recovered from 51 producing fields as shown in Table 1. Because equivalent rocks have been highly productive in nearby portions of Wyoming and eastern Colorado, it is difficult to explain their low yield in this region. Some suggested reasons are: 1) the Lower Cretaceous here is largely nonmarine, 2) the Mowry Shale (source bed) is thinner and 3) drilling has been mostly confined to shallow margins of basins near existing pipelines.

Past Exploration

In the early years of exploration in this region the Dakota Sandstone was envisioned as a blanket-like sand deposit and after discovery of oil at Hamilton dome it became a prime exploration target on all structural prospects. However, after many years of only scattered Dakota successes, it became apparent that there were other important controls. Geologists were then forced to make more detailed surface and subsurface investigations using modern stratigraphic and geophysical techniques. The result was the realization that facies changes and hydrodynamics play key roles in the entrapment of oil, and that most reservoirs are combination structural and stratigraphic traps. Principal known reservoir beds in this area are fractured neritic shales, bar or beach sands formed along the fluctuating shoreline, and channel sands of the braided stream subfacies.

Modern Concepts

It has been calculated (Sanborn, 1971) that Lower Cretaceous rocks of the Uinta and Piceance Creek basins have the potential of producing an additional 140-350 million barrels of oil and 212-590 billion cubic feet of gas. The present report excludes the western part of the Uinta basin but does include the Sand Wash basin which was not evaluated by Sanborn; therefore, the figures cannot be applied without some modification but do give an idea of the order of magnitude of possible recoverable resources.

If we assume that at least 200 million barrels of recoverable oil and 400 billion cubic feet of gas remain to be discovered in the Lower Cretaceous of this region, it is clear that the bulk must lie in the deeper portions of the three major basins. How then are we to locate these elusive reserves at depths ranging up to 16,000 feet in the Sand Wash basin, 20,000 feet in the east side of the Piceance Creek basin and 26,000 feet along the north edge of the Uinta basin? Dunn (1974) and Murray and Haun (1974) suggest that stratigraphically trapped hydrocarbons can be located by searching down-flank into deeper portions of the basins. Such searches will require detailed studies involving evaluations of well logs, determination and projection of environmental patterns, recognition and mapping of old structural trends, and confirmation of postulated structural features by geophysical techniques. Obviously these geophysical investigations will be mandatory for locating concealed structural features in the basinal deeps but some deeply buried fracture accumulations, or even structural traps, could be located using the suface fracture techniques described by Stearns and Friedman (1972) or perhaps by using ERTS images as suggested by Vincent (1975).

In conclusion it seems very likely that substantial reserves of Lower Cretaceous oil and gas remain to be found in this region, but discovering them will require an extremely concentrated geologic effort utilizing all present exploration techniques and probably necessitating the development of new ones. Precise geologic interpretations and projections will become a necessity because of increased drilling depths and the change from a multi-target structural play to a single target stratigraphic play.

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