LITHOFACIES AND RELATED HYDROCARBON ACCUMULATIONS IN TERTIARY STRATA OF THE WESTERN AND CENTRAL UINTA BASIN, UTAH

by
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ABSTRACT

Strata of Tertiary age in the Uinta Basin were deposited in an internally drained depression. They can be divided into (1) a central core of organic-rich open lacustrine claystone and mud-supported carbonate surrounded by (2) marginal lacustrine sandstone, claystone and mud- and grain-supported carbonate deposited in deltaic, interdeltaic, and lake-margin carbonate-flat environments, and (3) alluvial claystone, conglomerate, and sandstone units deposited peripheral to the lacustrine sediments.

The alluvial facies is not a major producer of hydrocarbons. However, overbank and channel sandstone units are gas-bearing on the south flank of the basin and are bitumen-bearing at Asphalt Ridge on the northeast margin of the basin. Marginal lacustrine strata including delta-front, overbank, and channel sandstone units contain the principal reservoirs for hydrocarbons in the Uinta Basin. Oil and gas appears to have been generated in open lacustrine source rock and trapped in marginal lacustrine reservoir units between rocks of the central open lacustrine facies and the peripheral alluvial facies.

Several correlation markers within the Green River Formation can be traced throughout the subsurface of the basin. From base to top they are the (1) lower marker, (2) Paleocene-Eocene boundary, (3) top of the carbonate marker unit, (4) middle marker, (5) Mahogany oil-shale bed, and 6) the upper marker. The oldest Tertiary units that yield large volumes of oil or gas are near the lower marker. Most production is from overpressured open and marginal lacustrine facies in the Altamont-Bluebell area. Overpressured marginal lacustrine units in the north central part of the Uinta Basin are the most prolific strata adjacent to the Paleocene-Eocene boundary. Oil and gas from rocks in the zone midway between the carbonate marker and Paleocene-Eocene boundary is generally overpressured and occurs primarily in the Altamont-Bluebell area. Rocks in the carbonate marker zone contain the youngest widely distributed overpressured beds. Overpressured fields are present along the north-central margin of the basin; however, fields near the south flank of the basin have normal pressures. The carbonate marker unit underlies a thick sequence of oil-stained marginal lacustrine facies extending from the center of the basin to the south flank. It has provided access to the outcrop of pressure release and fluid migration from the overpressured zone. Production of oil and gas from strata occurring near the middle marker is normally pressured. Marginal lacustrine units are the principal producing sequences in the middle marker zone, including those at Redwash field.

INTRODUCTION

The Late Cretaceous Epoch in central Utah witnessed an eastward regression of the marine shoreline in response to tectonism in the Sevier orogenic belt in western and central Utah. The regression produced a depositional sequence characteristically composed of open marine shale overlain by littoral sandstone units which in turn are succeeded by paludal and alluvial beds. Uplift which occurred in latest Cretaceous and early Tertiary time on the San Rafael, Uinta Mountain, and Uncompahgre structural elements disrupted the depositional pattern of Cretaceous sedimentation and resulted in the construction of a basin of internal drainage (Fig. 1). Rock sequences produced in the resulting Uinta Basin consist of coarse- and fine-grained basin filling which can be divided into a central core of organic-rich open lacustrine claystone and mud-supported carbonate surrounded by a marginal lacustrine facies consisting of sandstone, claystone, and mud- and grain-supported carbonate units deposited in deltaic, interdeltaic, and lake-margin carbonate-flat environments. Alluvial claystone, conglomerate, and sandstone beds were being deposited peripheral to the marginal lacustrine sediments.

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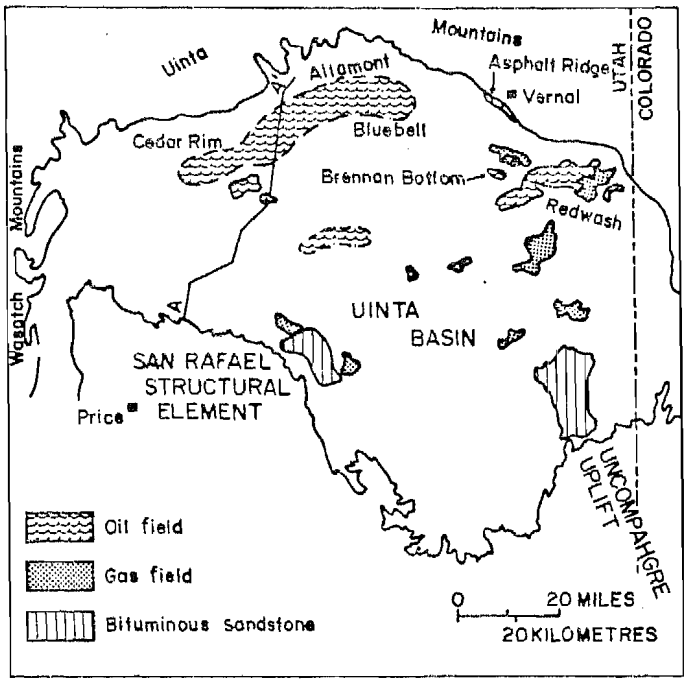

Fig. 1 — Index map of the Uinta Basin showing major oil and gas fields and bituminous sandstone deposits in Tertiary rocks, and line of section A-A' (Fig. 2).

More than one billion barrels of measured, indicated and inferred oil reserves and resources and additional billions of barrels of oil-in-place present in bituminous sandstones are contained in the marginal and open lacustrine deposits of the Green River Formation. Gas is produced from stratigraphic traps present in marginal lacustrine rocks of the Green River strata and from traps within the paludal-alluvial facies of the Colton, Wasatch and North Horn Formations. This paper suggests that hydrocarbon accumulations are in large part controlled by the type and distribution of lithofacies; each facies has a characteristic pattern of pressure gradient, drilling response, and production history.

STRATIGRAPHIC FRAMEWORK

Nomenclature

The Upper Cretaceous and lower Tertiary rocks in central and northeastern Utah were named by Spieker and Reeside (1925) and Spieker (1946) to identify mappable units which reflect lithofacies. Spieker described the Wasatch, Colton, and North Horn Formations as mostly variegated alluvial deposits. He considered the Flagstaff Limestone to intertongue with the Green River Formation between alluvial deposits of the underlying North Horn Formation and the overlying Colton Formation. Spieker (1946) stated that the Flagstaff records the beginning of widespread lacustrine conditions which continued uninterrupted through deposition of the Green River strata.

The nomenclature developed by Spieker and Reeside has been adopted and modified by petroleum geologists interested in the economic application of surface terminology to subsurface stratigraphy. The latter generally assign what is considered to be nonproductive strata containing red beds (their "Wasatch facies") to the Wasatch, Colton, and North Horn Formations. Rocks consisting of dark shades of gray and brown carbonate, sandstone, or claystone beds ("Green River facies" of petroleum geologists) have been assigned to the Green River Formation. Intervals containing mixed "Wasatch and Green River facies" are commonly grouped and termed "transition facies" (Baker and Lucas, 1972). The system generally proved adequate for subsurface economic studies; nevertheless, the assignment of an interval to a supposedly nonproductive facies because of the presence of some red beds was part of the reason that much of the lacustrine sequence (Flagstaff Member of the Green River) in the deeply buried part of the central and western Uinta Basin was not widely recognized prior to the discovery of the Altamont field (Lucas and Drexler, in press).

Figure 2 is a generalized structural-stratigraphic section from the exposures along the south-central flank of the Uinta Basin to the subsurface of the north-central part of the basin. A continuous section of organic-rich rocks of lacustrine origin in the center of the Uinta Basin has been penetrated by oil and gas tests drilled since 1969. Ryder, Fouch, and Elison (in press) extended the nomenclature to the central and western part of the basin in order to accommodate the results of both surface and subsurface studies.

North Horn Formation

The North Horn Formation has been identified in the subsurface of the Uinta Basin and includes variegated claystone, sandstone, conglomerate, and local deposits of coal and carbonate that are interpreted as alluvial, paludal, and lacustrine depositional facies. The North Horn is considered to be of latest Cretaceous and Paleocene age on the basis of vertebrate remains (Gilmore, 1940; Gazin, 1938, 1939, 1941) and the presence of palynomorph, ostracode, and charophyte assemblages (Grieser and MacAlpine, 1973, Newman, 1974).

Flagstaff Member of the Green River Formation

The Flagstaff Limestone (Spieker, 1946) was reduced in stratigraphic rank to Flagstaff Member of the Green River Formation in the central and western Uinta Basin by Ryder, Fouch, and Elison (in press). The Flagstaff as present at basin-perimeter outcrops is underlain by the North Horn Formation and overlain by the Colton Formation; however, in the central part of the basin the variegated rocks of the Colton grade laterally into brown carbonate, light-gray sandstone, and light-gray to gray-

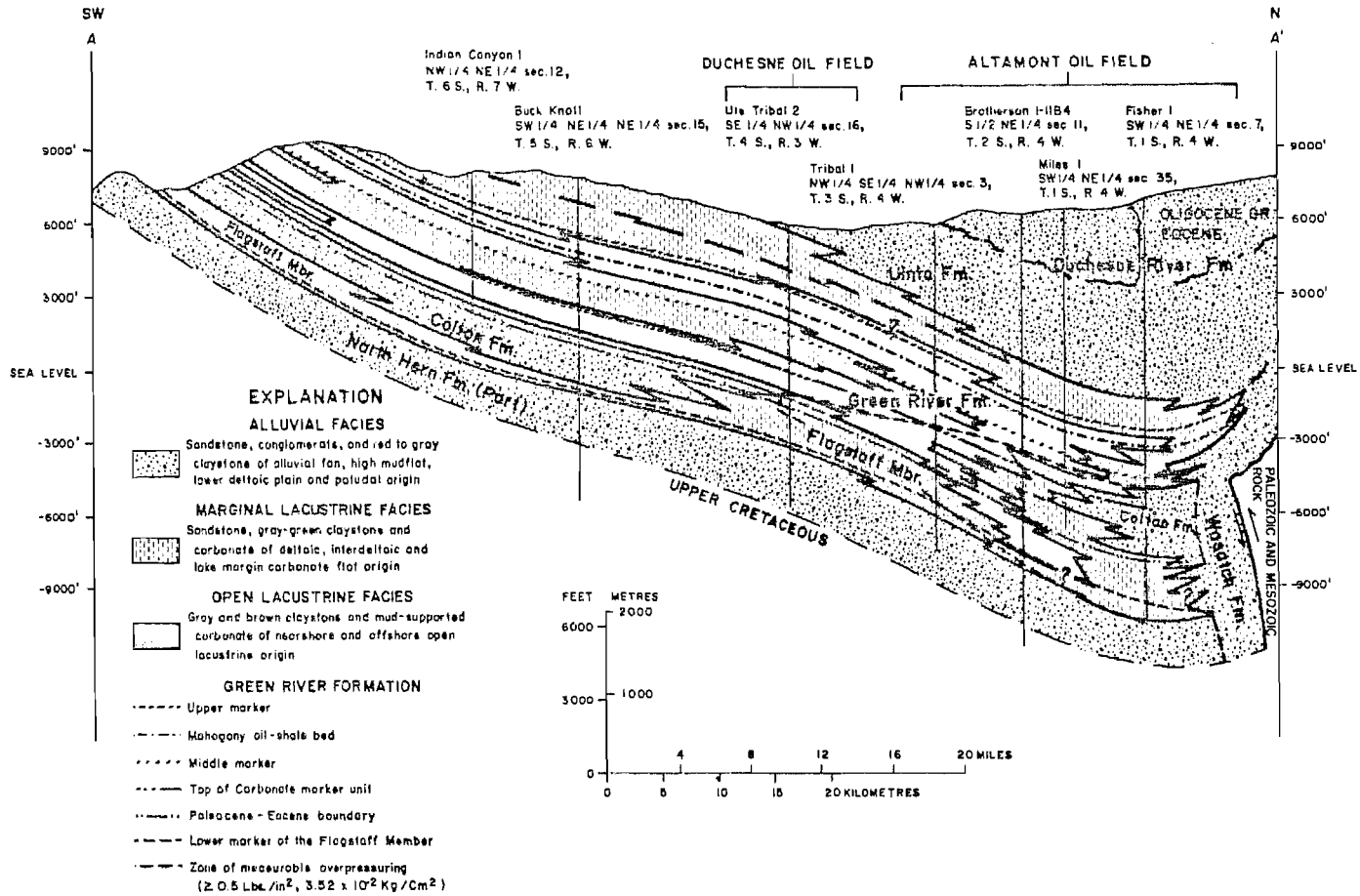

Fig. 2 — Generalized structural-stratigraphic cross section from outcrops on the southwest flank of the Uinta Basin, through Duchesne and Altamont-Bluebell oil fields, to the north-central part of the basin. Uinta Formation includes saline facies and equivalent lacustrine rocks assigned to the Uinta by Dane (1954).

green claystone of the Green River Formation. Figure 2 shows that the lower part of this sequence of lacustrine rocks present in the central Uinta Basin can be mapped continuously from outcrops of the Flagstaff on the south flank of the basin to the subsurface of the central and western Uinta Basin where it is part of the Green River Formation. Ryder, Fouch. and Elison (in press) cite microfossil evidence from the subsurface which indicates uninterrupted deposition within this Paleocene and early Eocene sequence.

Colton Formation

A thick section of sandstone and red claystone is present on the north side of the basin beneath the main body of the Green River Formation and overlying the Flagstaff Member of the Green River Formation. Ryder, Fouch, and Elison (in press) demonstrate that this red bed sequence is continuous in the subsurface of the east-central part of the basin with the Colton Formation on the southwest flank.

Wasatch Formation

The term Wasatch Formation has been used to describe a variety of rocks of differing physical description, age, and origin. Spieker (1946) elevated the members (lower, Flagstaff, and upper) of the Wasatch Formation to formation status (North Horn, Flagstaff, and Colton Formations) and subsequently did not use the term Wasatch to denote strata contained in the former members. However, prompted by the widespread use of the term for any variegated strata of Paleocene and early Eocene age, Ryder, Fouch, and Elison used the term in the central and western parts of the Uinta Basin so as to refine its stratigraphic meaning. Where the Flagstaff Member of the Green River Formation is not present to separate the variegated rocks of the Colton and North Horn Formations and to assure stratigraphic identity, the designation as Wasatch Formation is preferable to a doubtful separation.

Surface and Subsurface Markers

Figure 2 shows the stratigraphic positions of several markers in the Green River Formation which can be traced from the surface throughout the subsurface of much of the basin. The oldest subsurface marker of Tertiary age which can be correlated with confidence in the central and western parts of the Uinta Basin is called the lower marker of the Flagstaff Member. The lower marker occurs near the base of the Flagstaff and is generally identified in the subsurface by a mechanical log response indicating the boundary between a claystone overlying a calcareous siltstone or sandstone. The lower marker occurs at 14,000 ft (4,267 m) in the Shell Brotherson 1-11B4, S ½ NE ¼ sec. 11, T. 2 S., R. 4 W. Ryder, Fouch, and Elison (in press) place the Paleocene-Eocene boundary in the upper third of the Colton Formation on the south-central flank of the basin and near 12,400 ft (3,780 m) in the Shell Brotherson 1-11B4, on the basis of palynomorph, charophyte, and ostracode assemblages. The carbonate marker unit is the best outcrop marker in the lower part of the Green River Formation (Ryder and others, in press). The unit forms a well-defined cliff composed of mud-supported carbonate beds (98 ft (30 m) thick) in the Willow Creek-Indian Canyon area in the southwest part of the basin. The horizon at the top of the carbonate marker unit can be confidently carried throughout most of the subsurface part of the basin and occurs at 10,565 ft (3,200 m) in the Shell Brotherson 1-11B4. Another prominent marker was termed by Ryder, Fouch, and Elison as the middle marker of the Green River Formation (Tgr 3 of Baker and Lucas, 1972). The middle marker in the subsurface of much of the basin indicates the boundary between a gray-green calcareous claystone and an underlying mud-supported carbonate. The middle marker occurs at 9,300 ft (2,835 m) in the Shell Brotherson 1-11B4. The best subsurface and surface marker in the Green River Formation is the Mahogany oil-shale bed (Bradley, 1931; Cashion, 1967; Cashion and Donnell, 1972) which is present in both the Uinta and Piceance Creek Basins. The Mahogany oil-shale bed is present in the Shell Brotherson 1-11B4 at a depth of 8,045 ft (2,452 m) and can be traced with the aid of mechanical logs. The top of the interval containing the Horse Bench Sandstone Bed (Bradley, 1931; Cashion, 1967) and equivalent units is here referred to as the upper marker of the Green River Formation. The upper marker occurs in the Shell Brotherson 1-11B4 at a depth of 7,410 ft (2,259 m). The Cretaceous-Paleocene boundary is located in the lower part of the North Horn Formation on the south flank of the basin (Griesbach and MacAlpine, 1973; Newman, 1974) and near a depth of 17,000 ft (5,180 m) in the Shell Brotherson 1-11B4 (S. R. MacAlpine, oral commun., 1971-74).

Major Facies and Depositional Environments

The uppermost Cretaceous and lower Eocene strata within the central and western parts of the Uinta Basin below the middle marker have been divided into three major intertonguing lithofacies, as determined from surface and subsurface data (Fouch and others, 1973; Ryder and others, in press): (1) open lacustrine, (2) marginal lacustrine, and (3) alluvial. The major facies are applied here to rocks above the middle marker; however, the author recognizes that significant variations are present. The following brief description of each lithofacies is summarized from the work of the above authors. The reader is referred to their publications for a discussion of the complex evolution of Lake Uinta and a more complete treatment of the sedimentology and physical stratigraphy and description of the depositional environments. A knowledge of these rock facies is fundamental to understanding the generation and entrapment of hydrocarbons in the Uinta Basin.

Alluvial Facies

The alluvial facies is composed primarily of argillaceous sandstone, conglomerate, siltstone, and claystone. The facies is characterized by red beds; however, the lower parts of the Wasatch and the North Horn Formations commonly contain only a small percentage of red units. The rocks present in the alluvial facies are interpreted to have been deposited as lower deltaic plain, high mudflat; alluvial fan, and paludal sediments.

The lower deltaic plain environment is peripheral to the deltaic environment of the marginal lacustrine facies. Rocks deposited in the lower deltaic plain environment include thin to medium horizontally bedded red claystone beds which contain well-developed polygonal mud cracks and local burrow structures. The claystones are commonly interbedded with thin-bedded siltstone and sandstone units exhibiting both massive bedding and small-scale crossbeds. Composite fluvial channel-form sandstone units characterize the lower deltaic plain environment, and the adjacent claystone and sandstone beds are interpreted as overbank deposits.

The high mudflat environment is laterally adjacent to the lower deltaic plain setting and contains red claystone, isolated minor channel-form sandstone units, and in the subsurface anhydrite nodules. Rocks of the high mudflat environment are interpreted to have been deposited on a clay-dominated mudflat which was subject to long periods of subaerial exposure.

The alluvial fan environment is located adjacent to ancient mountain fronts and is present along the west and north flanks of the basin. Conglomerate, sandstone, siltstone and red claystone are the principal rocks types. The units represent anastomosing braided channel deposits and

exhibit thick, massive to crudely stratified subhorizontal beds.

Rocks interpreted to have been deposited as paludal sediments are present in the subsurface within the alluvial facies. In the central and north-central part of the basin, the North Horn Formation contains abundant coal, carbonaceous shale, and silty sandstone beds commonly colored shades of gray, with red hues less conspicuous. Carbonate units are rare to absent. All these rocks are interpreted as sediments deposited in a somewhat swampy reducing environment where ponded water bodies contained much woody plant material. This environment contrasts with the widespread algae-dominated lacustrine units of the main body of the Green River Formation.

Marginal Lacustrine Facies

The marginal lacustrire facies is composed of sandstone, claystone, and mixed grain and mud-supported carbonate units. The predominant claystone colors range from light- and medium-gray to gray-green. Rocks present in the marginal lacustrine facies are interpreted to have been deposited in deltaic, interdeltaic, and lake-margin carbonate-flat environments.

The lake-margin carbonate-flat environment is peripheral to the open lacustrine and adjacent to the deltaic setting. Lake-margin carbonate-flat units within the Flagstaff Member of the Green River Formation grade systematically basinward from (1) intercalated sandstone, gray claystone, algal coal, and oncolite-grain-supported carbonate to (2) highly fossiliferous mud and skeletal grain-supported carbonate to (3) dark-gray mud-supported carbonate of the open lacustrine lithofacies. The intercalated sandstone units commonly contain small-scale crossbeds (current ripples) and burrow structures and are channel-form.

Lake-margin carbonate-flat rocks present in the main body of the Green River Formation grade basinward from (1) oolitic and ostracodal grainstones containing horizontal and low-angle crossbeds and thin horizontally bedded minor sandstone to (2) gray horizontally bedded grain- and mud-supported carbonate beds to (3) brown kerogenous ostracodal mud-supported carbonate of open

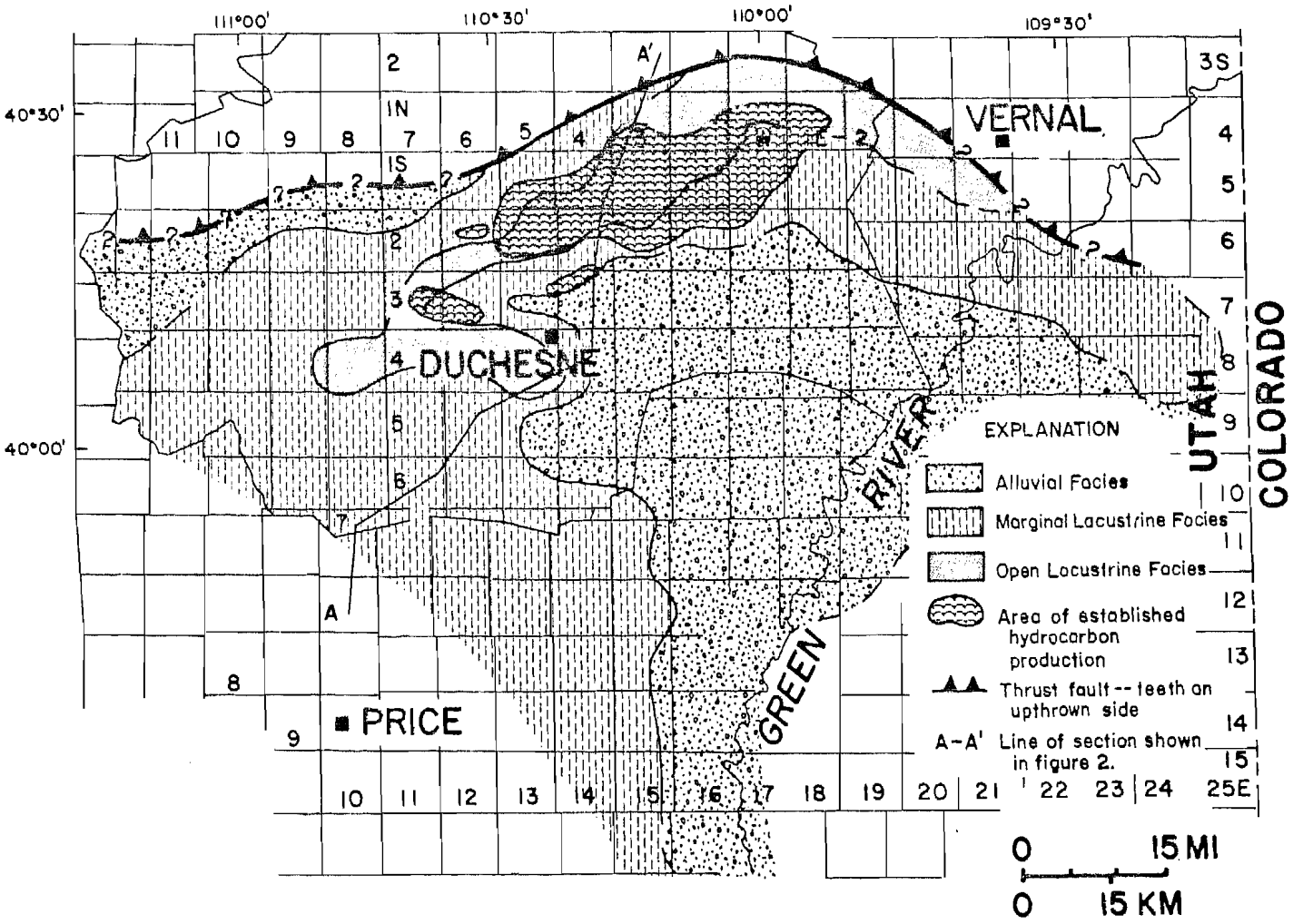

Fig. 3 — Generalized lithofacies map showing areas of established production from a zone consisting of beds adjacent and laterally equivalent to the lower marker of the Flagstaff Member of the Green River Formation.

lacustrine origin. Sedimentary structures present in the setting include current ripple marks, large polygonal mud cracks, sedimentary breccias, small- and medium-scale crossbeds, thin to medium horizontal beds, and algal boundstone stromatolites. The numerous ostracodal grainstone and packstone units, which are commonly capped by oolitically coated grains, are interpreted as shoal and beach deposits.

The deltaic environment is peripheral to the open lacustrine setting and is represented mainly by sandstone, siltstone, and gray-green claystone. Individual and composite channel-form sandstone units are prominent. Where exposed on the south flank of the basin, these fluvial units appear to have been deposited by distributary streams developed on a broad gently sloping surface in shallow lake waters. Energy provided by the shallow lake water was apparently low, for the channel-form deposits were not redistributed to form extensive beach or lacustrine bar deposits. Associated thin-bedded sandstone, siltstone, and claystone units are interpreted to represent delta-front and crevasse-splay deposits.

The interdeltaic environment is located along depositional strike from the deltaic environment. Major rock types found in the environment are siltstone, sandstone, and gray-green claystone. Beds representing the interdeltaic environment commonly intertongue with units of adjacent environments, an occurrence common to beds of all adjacent lithofacies. As is true in the deltaic environment channel-form bodies are the characteristic sandstone units present except that channels are generally smaller in the interdeltaic environment, and interbedded claystone and lake-margin carbonate-flat carbonate units are more abundant. The setting was periodically exposed to subaerial conditions, as evident from the mud cracks, clay clasts, and some thin red and red mottled claystones.

Open Lacustrine Facies

The open lacustrine facies is composed primarily of calcareous claystone and mud-supported carbonate. Organic compounds impart black and darker shales of gray and brown color to the rocks. An assemblage of thin horizontal laminae is the major bedding type but loop

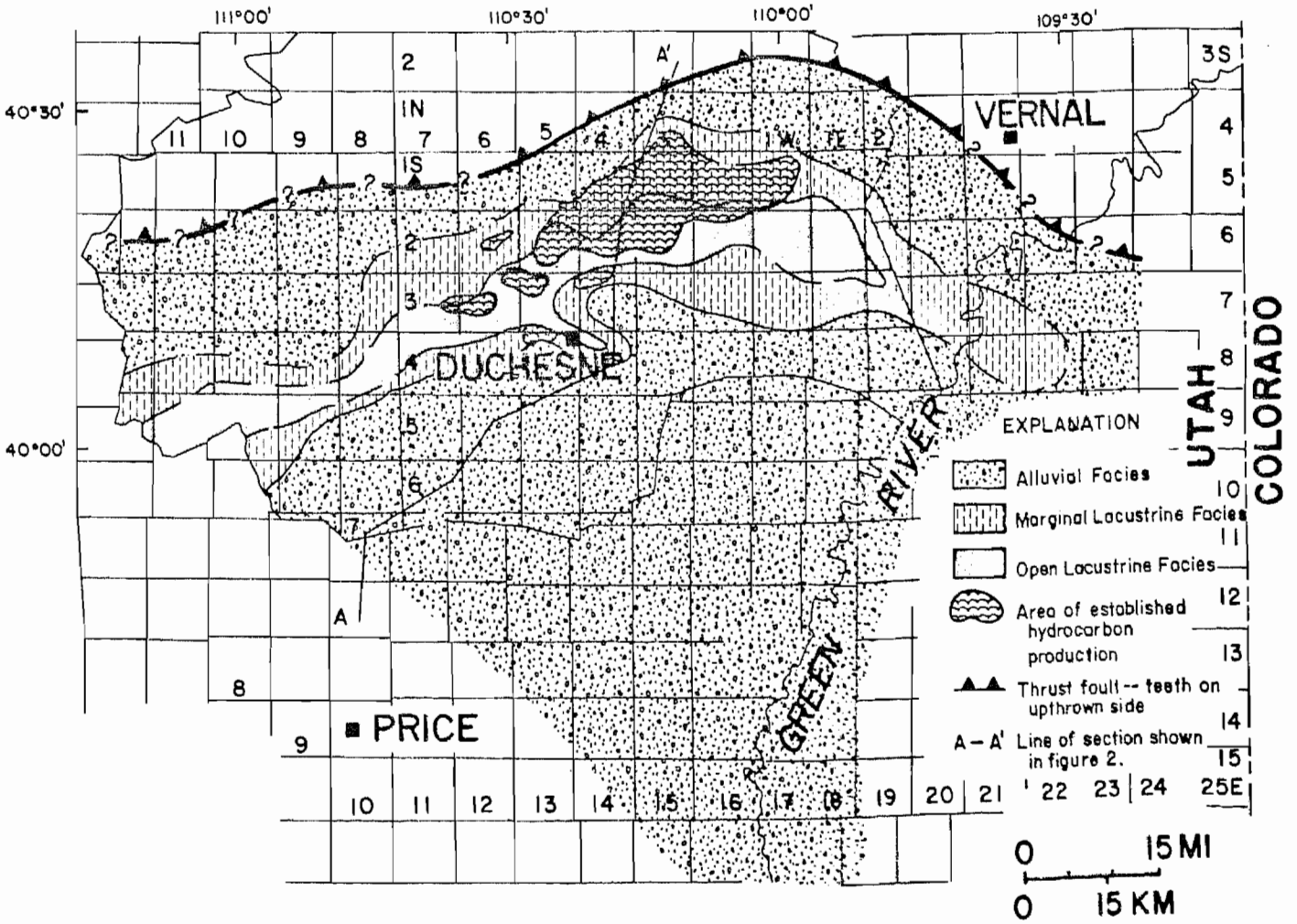

Fig. 4 — Generalized lithofacies map showing areas of established production from a zone consisting of beds adjacent to the Eocene-Paleocene boundary.

beddings, curviplanar laminae, convolute beds, and associated penecontemprancous small-scale faults are present. In addition, desiccation features are present in some rocks of the open lacustrine facies. The rocks present in the lacustrine facies are interpreted to have been deposited as nearshore and offshore open lacustrine sediments.

STRATIGRAPHIC CONTROL OF HYDROCARBON ACCUMULATIONS

Regional Facies Patterns and Productive Areas

Figures 2 through 7 illustrate the stratigraphic framework of strata of Tertiary age within which the occurrence of facies and associated hydrocarbon accumulation can be related. Figures 3 through 7 are lithofacies maps of zones consisting of beds generally within 200 feet vertically adjacent to markers illustrated on Figure 2. Potential productive intervals, relative field size, and lithofacies can, with the aid of these illustrations, be estimated for many rock intervals in the western and central Uinta Basin. Further, the limits of the overpressured rocks can be approximated by utilizing the maps and section to determine the position where the relatively permeable marginal lacustrine facies may have provided permeability channels to the outcrop and subsequently reduced fluid pressure.

Figure 3 is a lithofacies map of a zone consisting of beds adjacent and laterally equivalent to the lower marker of the Flagstaff Member of the Green River Formation showing most areas of established production from this interval. A central open lacustrine core trends northeast and may terminate at a major reverse fault on the south flank of the Uinta Mountains (Lucas and Drexler, in press). Rocks of marginal lacustrine and alluvial origin flank the open lacustrine facies and form a prominent wedge which extended northwestward into the lake. Carbonate rocks deposited as lake-margin carbonate-flat sediments dominate the southwest flank of the basin.

Rocks in this interval are the oldest of Tertiary age in the Uinta Basin which have yielded large volumes of oil or gas. Most production is from overpressured sequences in the Altamont-Bluebell area, where both marginal and open lacustrine units yield hydrocarbons. Alluvial rocks of the North Horn Formation underlie much of the pro-

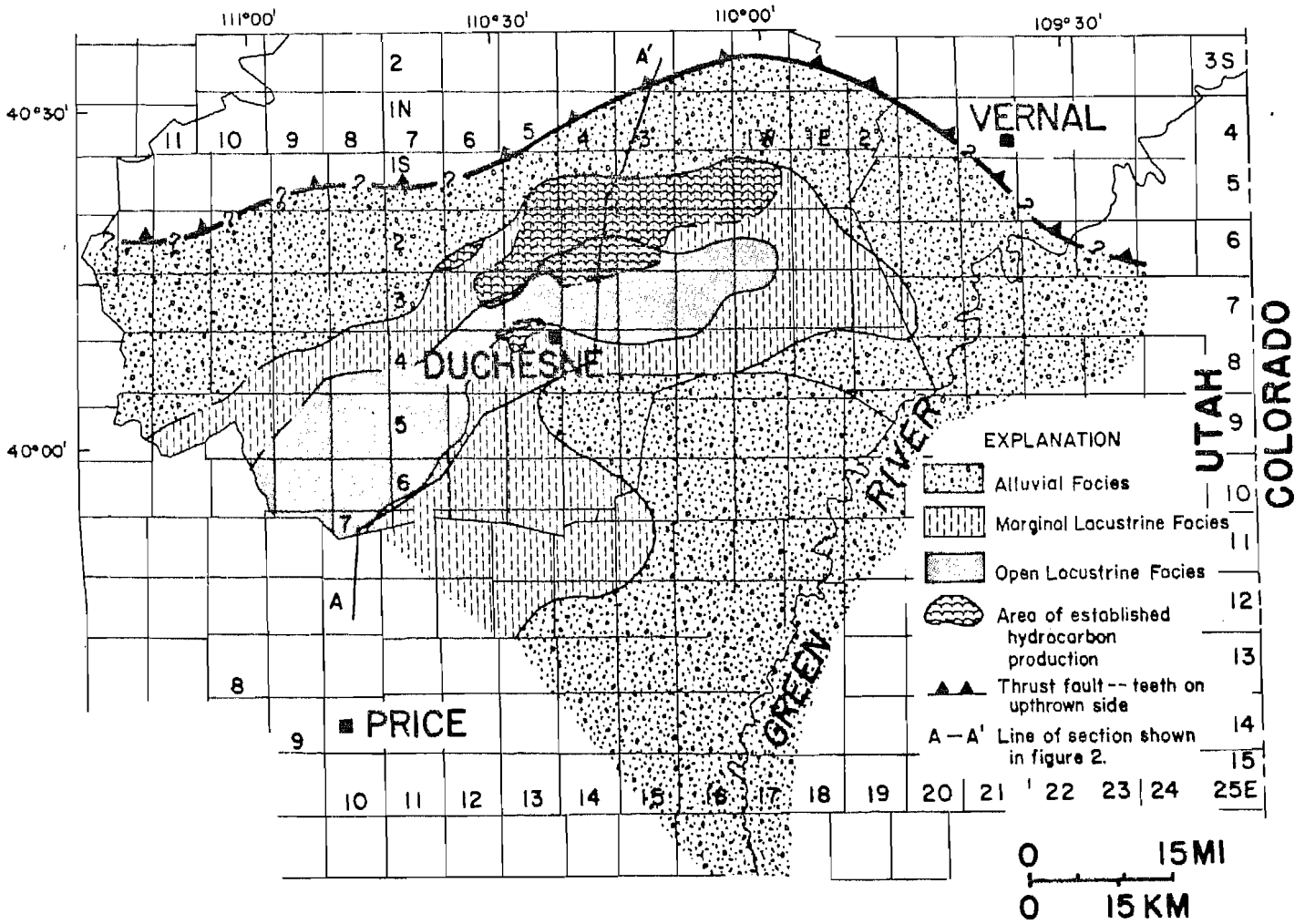

Fig. 5 — Generalized lithofacies map showing areas of established production from a zone consisting of beds midway between the carbonate marker of the Green River Formation and the Eocene-Paleocene boundary.

ductive area at Altamont-Bluebell, and fluid pressure gradients seem to decrease in the North Horn, where continuity to the outcrop along the south flank of the basin may have provided an avenue for pressure escape.

Figure 4 shows the lithofacies and productive area for a zone consisting of beds adjacent and laterally equivalent to the Paleocene-Eocene boundary. A narrow east-west central core of open lacustrine rocks is flanked by marginal and alluvial facies. The marginal lacustrine facies was restricted to a narrow band on the north and south sides of the lake. Most production from this interval is from overpressured rocks. Rocks of the marginal lacustrine facies are also productive in the Carter Ute Tribal 2, C SE ¼ NW ¼ sec. 16, T. 4 S., R. 4 W., at the northern tip of a tongue of the Colton Formation (Fig. 2). The productive interval is overpressured and may mark the southernmost extent of the overpressured (>0.5 lbs/in^2) section in the central part of the Uinta Basin.

Although the open lacustrine facies is productive near the Paleocene-Eocene boundary, the most sustained production has been established in the marginal lacustrine facies. Overpressuring appears to be necessary for production of large volumes of oil from rocks of this age, inasmuch as individual accumulations located near the perimeter of the overpressured area are relatively small (less than 5 million barrels measured reserves). However, producing intervals in fields adpacent to areas of overpressured production often occur at shallower drilling depths and commonly contain greater matrix porosities within reservoir units than are present in similar reservoir beds in the Altamont-Bluebell area.

Figure 5 illustrates the lithofacies and productive area for a zone consisting of strata located midway between the carbonate marker and the Paleocene-Eocene boundary. The lithofacies pattern consists of the central core of open lacustrine units oriented southwest-northeast and surrounded by successive halos of marginal lacustrine and alluvial facies. Lacustrine rocks are confined to an area west of the Green River. The pattern of red beds in the subsurface around the east boundary of the lacustrine

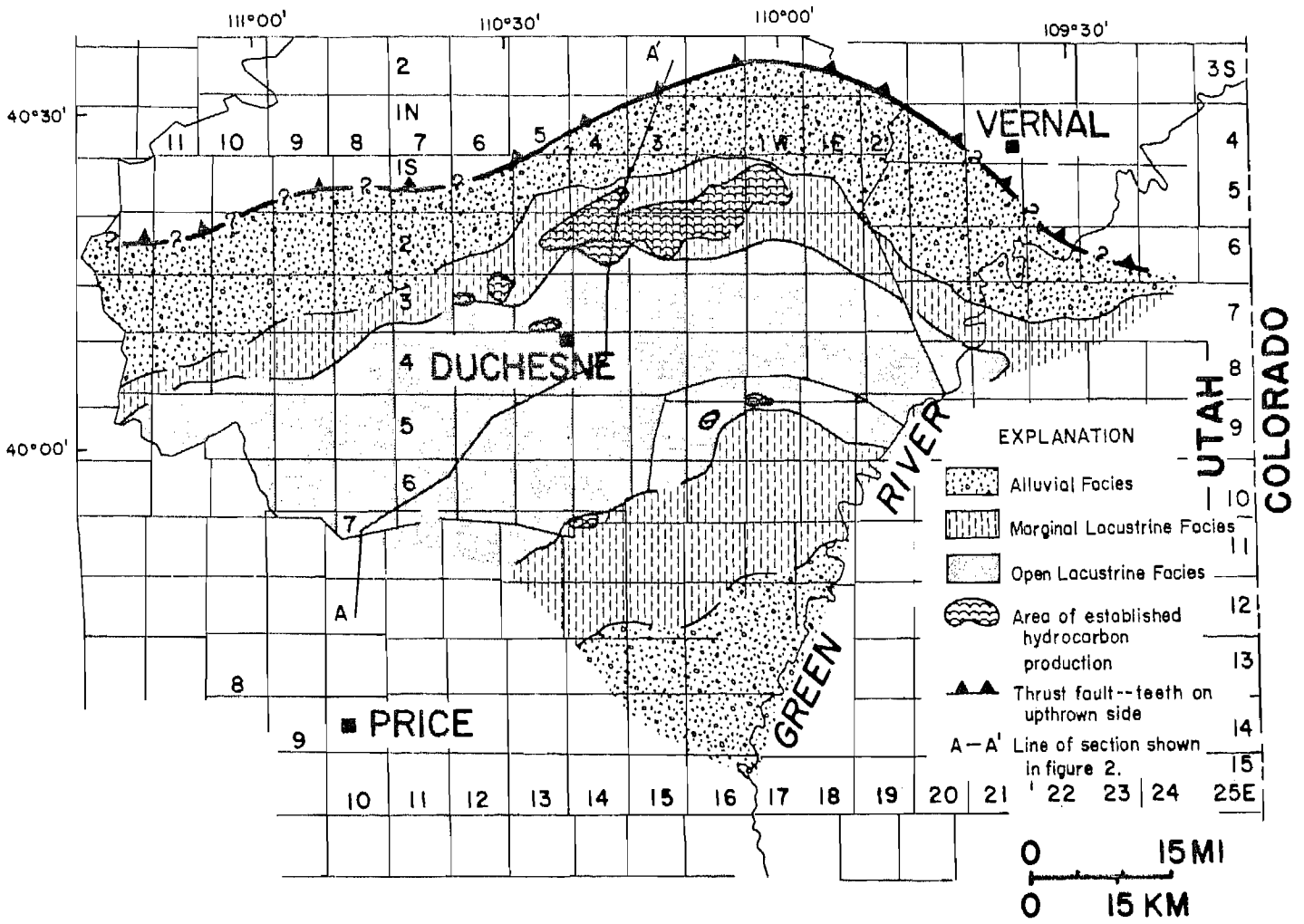

Fig. 6 — Generalized lithofacies map showing areas of established production from a zone consisting of beds adjacent and laterally equivalent to the carbonate marker of the Green River Formation.

units joins alluvial rocks of the Colton Formation on the southwest flank of the basin with red beds of the Colton Formation on the north side of the basin.

Production of oil and gas from rocks in the zone midway between the carbonate marker and Paleocene-Eocene boundary is generally overpressured and occurs mainly in the Altamont-Bluebell area in the northern part of the Uinta Basin. Rocks of marginal lacustrine lithofacies constitute the primary productive units. Marginal lacustrine rocks along the east and southern margins of the lacustrine system are normally pressured.

Figure 6 illustrates the lithofacies and associated productive areas of a zone consisting of beds adjacent and laterally equivalent to the top of the carbonate marker. The wide, open lacustrine belt trends east-west and is flanked by a narrow band of marginal lacustrine rocks on the north side of the basin and a broader belt on the south margin. This interval contains the greatest expanse of open lacustrine rocks in the southwest flank of the basin below the carbonate marker.

Rocks of the carbonate marker zone are slightly overpressured in the northern lacustrine facies. Known fields in equivalent rocks on the south flank of the basin occur at relatively shallow depths in normally pressured units. However, numerous additional stratigraphic traps may exist on the south flank because exposures of oil-impregnated units are commonly found in channel-form sandstone bodies.

The carbonate marker zone is located near the upper limit of the overpressured units. Ryder, Fouch, and Elison (in press) demonstrate that the carbonate marker directly underlies a thick and extensive sequence of marginal rocks that extends northward from the south flank of the basin. Figure 2 demonstrates that this marginal lacustrine sequence seems to overlie the overpressured units, and so it is reasonable to assume that the sequence provided access to the outcrop for pressure and fluid escape.

The lithofacies and productive areas of a zone consisting of beds adjacent and laterally equivalent to the middle marker of the Green River Formation are shown on Figure 7. A narrow east-west band of open lacustrine facies extends to the large Redwash field at the east end

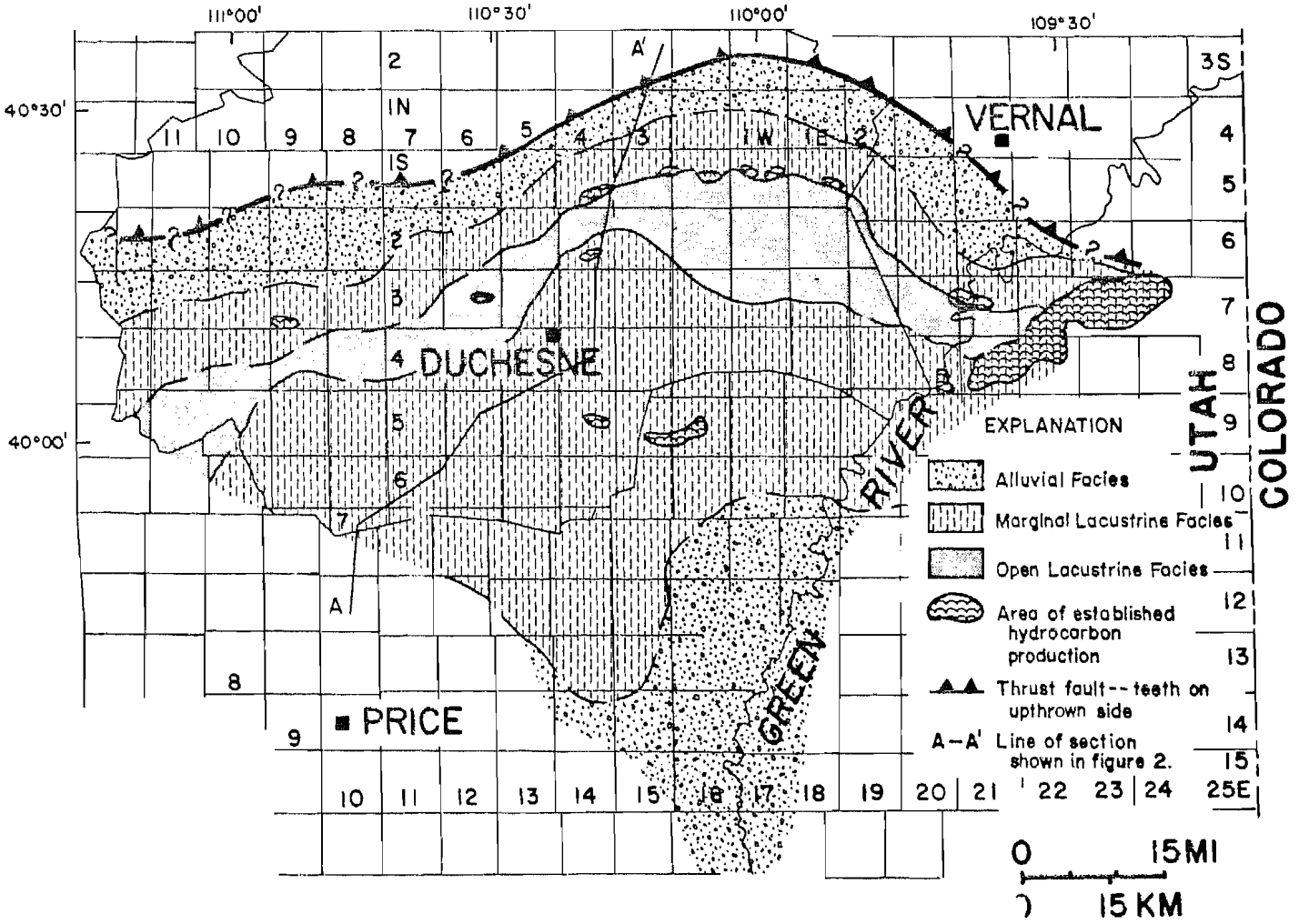

Fig. 7 — Generalized lithofacies map showing areas of established production from a zone consisting of beds adjacent and laterally equivalent to the middle marker or of the Green River Formation.

of the basin. The northern marginal lacustrine belt is narrow, and the southern flank is an extremely broad band of marginal lacustrine units.

Production of oil and gas from the zone of the middle marker is normally pressured. The principal producing units, including those in Redwash field, are in marginal lacustrine facies. With the exception of Redwash field, individual accumulations found in this interval average less than 5 million barrels of measured and indicated reserves.

Facies and Related Reservoir Units

The marginal lacustrine facies contains the primary reservoir rocks in the major oil and gas fields of the Uinta Basin. Porosity developed within delta-front, overbank, and channel sandstone units provide most of the storage capacity for hydrocarbons in the deeply buried Tertiary rocks of the western part of the Uinta Basin. Wells completed in normally pressured and overpressured rocks of the marginal lacustrine facies maintain their productive capacity for much longer periods than wells completed in rocks of other facies. The intercalated marginal and open lacustrine rocks provide contrasts in ductility between the brittle mud-supported carbonates of the open lacustrine setting and relatively ductile claystones of the marginal lacustrine facies. This intimate interbedding of beds of highly contrasting ductility has influenced the frequency of fractures which apparently provide much of the permeability needed to drain the low porosity reservoir units (Lucas and Drexler, in press).

Extensive reservoir bodies have not been documented at depths below 10,000 ft (3,048 m) in carbonates deposited in the lake-margin carbonate-flat environment. Nevertheless, oolitic ostracodal grainstones are productive in some intervals near and above the carbonate marker in the Bluebell, Brennan Bottom and Redwash fields. In addition, oolite and ostracodal grainstone and packstone beds, and algal boundstone stromatolites found near the carbonate marker are oil-stained on outcrops along the basin's southwest flank.

Bituminous sandstone accumulations occurring in Tertiary age rocks of the Uinta Basin are contained within units interpreted to be of the marginal lacustrine facies. Both carbonate and siliciclastic rocks deposited as deltaic, interdeltaic, and lake-margin carbonate-flat sediments form major reservoir bodies which are impregnated with hydrocarbons.

Some thin discontinuous fine-grained sandstone beds occur in the open lacustrine facies. However, most sandstone units interbedded with open lacustrine claystone and carbonate beds occur near the perimeter of the environment and are interpreted as delta front beds of the deltaic environment because they can be traced laterally into sandstone beds that are clearly of the marginal lacustrine lithofacies. The delta-front units commonly are less than 1 ft (0.3 m) thick and can be difficult to identify in the subsurface when only drill cuttings and mechanical logs are available. Many similar thin sandstone beds of potential reservoir quality may provide storage capacity for oil and gas being produced from an apparent reservoir-free open lacustrine sequence in the northern Uinta Basin.

The alluvial facies is not generally considered to be a major oil-producing assemblage. Though the facies is relatively impermeable in the deeply buried Tertiary rocks, alluvial overbank and channel-sandstone reservoirs are gas bearing along the south flank of the basin, and rocks of alluvial origin within the Duchesne River Formation are hydrocarbon bearing at Asphalt Ridge in the northeast part of the basin (Covington, 1964).

CONCLUSIONS

Rocks of Tertiary age in the Uinta Basin were deposited in environments important to the generation and entrapment of hydrocarbons. The North Horn, Colton, and Wasatch Formations consist of variegated rocks deposited as alluvial sediments whereas the Green River Formation is interpreted to be composed of units of the marginal and open lacustrine environments.

Within the Tertiary strata, hydrocarbons which seem to have been generated in open lacustrine source rock were trapped in pores developed in marginal lacustrine sandstone and grain-supported carbonate units between the relatively impermeable central open lacustrine beds and the alluvial claystone and sandstone. Overpressured rocks occur near and below the carbonate marker and are bounded by relatively permeable marginal lacustrine units continuous to the outcrop. The stratigraphy of producing zones in Redwash, Bluebell, Altamont, and numerous smaller fields is controlled by the depositional framework developed in the Uinta Basin lacustrine system.

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