UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

Hydrocarbon potential of Eastern Mesozoic Basins

by

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Open-File Report 88-299

1988

1. Reston, Virginia

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ABSTRACT:

Rocks of the Eastern Mesozoic Basins of North America have a viable hydrocarbon potential. Source and reservoir rocks are present and thermal maturities are within the oil and gas generation ranges. Structural and stratigraphic traps are present in all the basins. Although oil and gas shows have been documented for the last 70 years, no producing well has been completed. Drilling in the basins continues today.

INTRODUCTION:

The Eastern Mesozoic Basins (Fig.1) comprise a total area of approximately 42,732 mi (110,684 km) extending from Georgia to northern the Massachussets border. Individual basins, however are much smaller(Table 1). Approximately 2,000 mi (5,000 km) of this area is Federal land, consisting of relatively small individual holdings. In this report, the Mesozoic basin play consists of the exposed basins in the Appalachian Piedmont and Blue Ridge provinces and the inferred basins below Cretaceous, Tertiary, and Holocene sediments of the Coastal Plain province(Fig. 1). Since little is known about the inferred Mesozoic basins below Coastal Plain sediments, the discussion on the geology of them will be limited to an analogy with the basins that are exposed to the west(Fig.1). A summary of the geology and hydrocarbon associations of the clastic and carbonate rocks of the Coastal Plain is included in Libby-French(1985).

GENERAL GEOLOGIC SETTING

The Newark type (Manspeizer, 1981) extensional basins are a series of elongate, asymmetric, pull-apart or half-graben structures which contain thick, upper Triassic through lower Jurassic continental clastic, carbonate, and volcanic rocks. The basin fill rocks rest unconformably on the crystalline rocks of older Acadian and Alleghanian orogenies (Manspiezer, 1981). Major sedimentary rock types are reddish-brown mudstone, course-grained polymict "border" conglomerate and fanglomerate, arkosic sandstone and siltstone, and gray to black lacustrine shale and carbonate with coal. Tholeiitic basalt flows are common in the northern basins whereas sills and dikes are concentrated in the southern basins. These igneous rocks are thought to have been generated and emplaced during sedimentation following major basin deposition (Manspiezer,1981).

A tectonic synthesis of basin evolution(Manspiezer, 1981) includes:

1. Permian(?) through Early Triassic crustal thinning which followed major Appalachian compressional tectonics along the eastern margin of the North American continent. This is the earliest stage of continental breakup of the super continent Pangea(Fig.2).

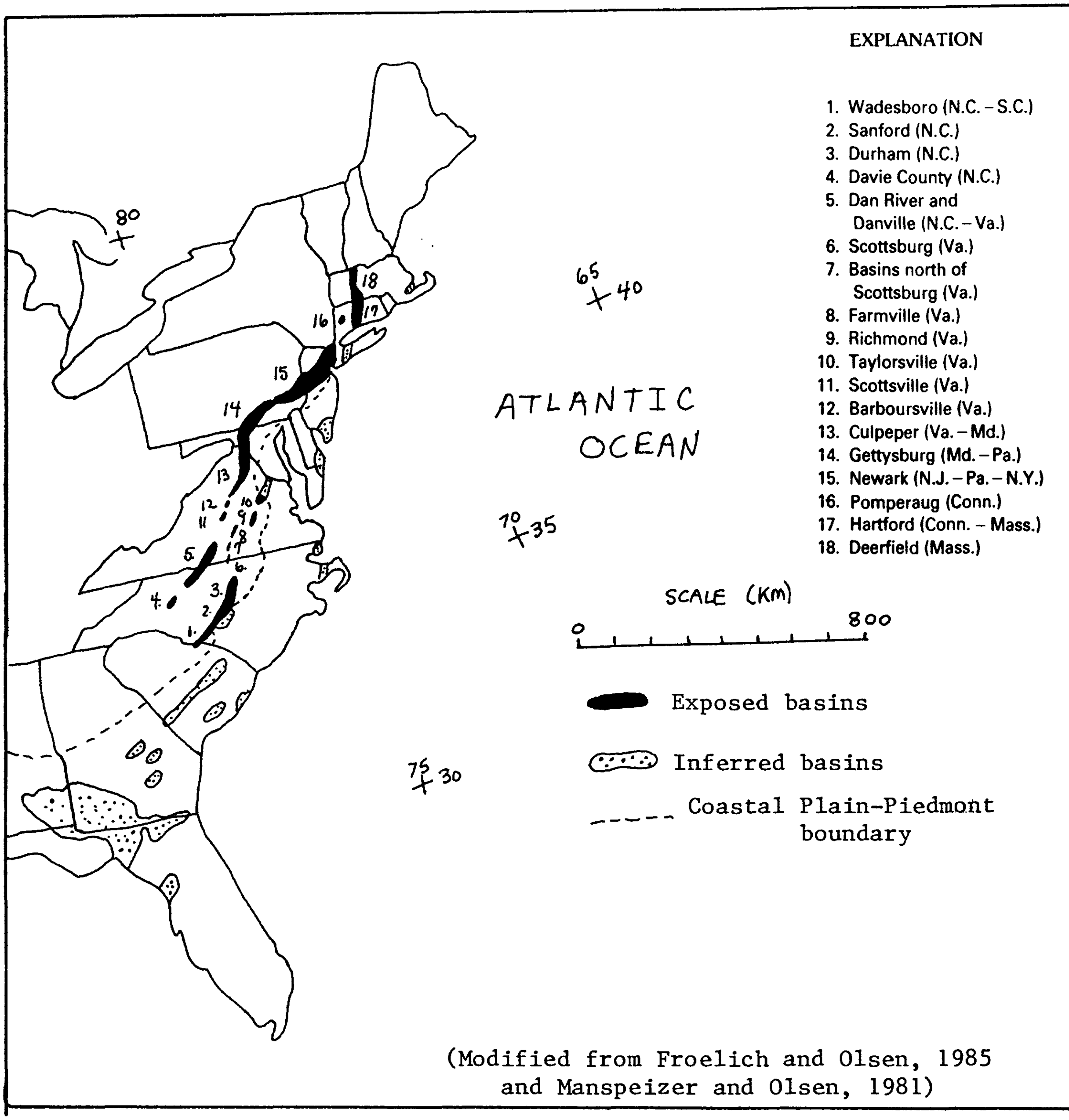
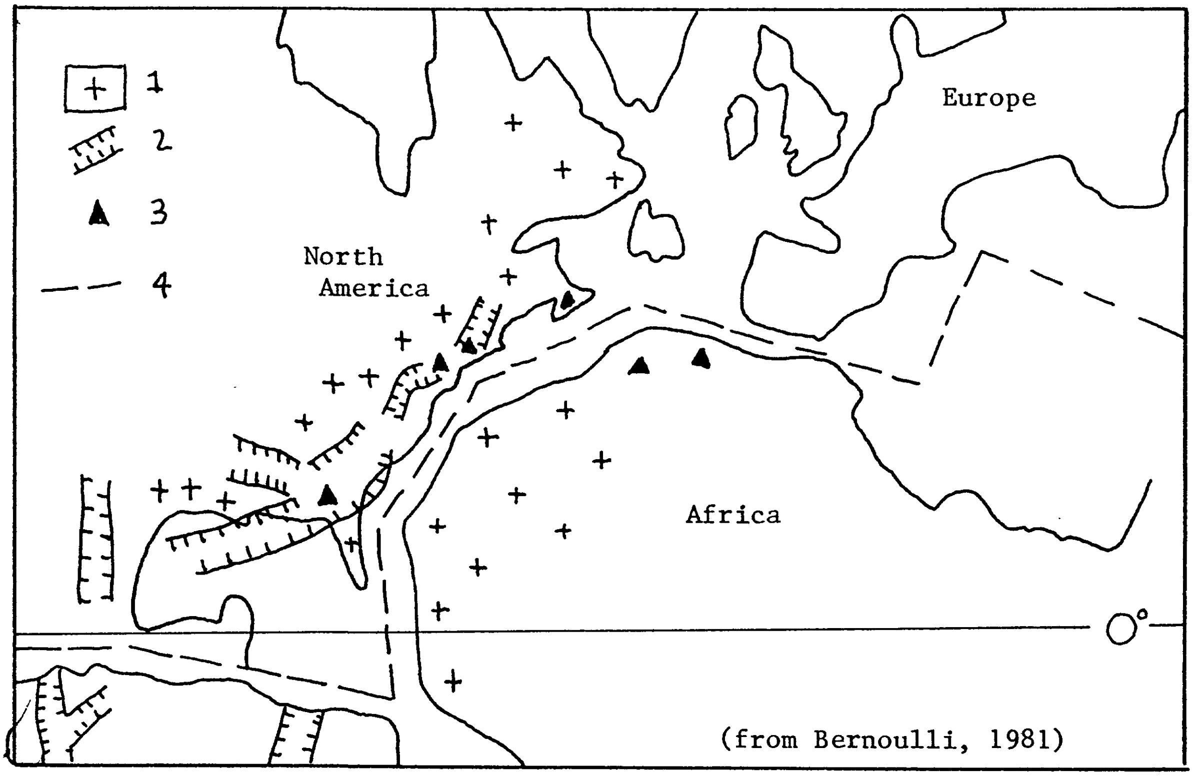


Figure 1. Index map of exposed and inferred Mesozoic basins of Eastern North America and Coastal Plain-Piedmont boundary. Map modified from Froelich and Olsen, 1985 and Manspeizer and Olsen, 1981.



Key: 1. continental areas with erosion of local continental sediments
2. grabens filled with continental clastics
3. volcanics and intrusives
4. site of breakup along the Jurassic Tethys

Figure 2. Palinspastic tectonic restoration of Late Triassic paleogeography (modified from Bernoulli, 1981), prior to major breakup of Pangea. Note location of rift basins along the eastern margin of North America.

2. Middle Triassic rifting and crustal extension followed by latest Triassic clastic deposition into the evolving basins.
3. Early Jurassic continuation of extension and clastic deposition in basins with major tholeitte igneous activity.
4. Lower to Middle Jurassic sea-floor spreading and development of Mid-Atlantic ridge basalts.
5. Post Jurassic to present lithospheric cooling, plate subsidence and marine transgression with development of a passive continental margin.

EXAMPLE BASIN:

Within individual basins, rift related structures are complex(Fig. 3). Models for the development of the basins (Manspeizer and Olsen, 1981; Ratcliffe and Burton,1985) include a variety of oblique normal faults, strike-slip faults and oblique normal faults along pre-existing thrust faults in the underlying crystalline basement rocks. Structures within basins (Fig. 3) consist of extensional border faults with some component of oblique slip and a domain of trans-tensional folds and faults within the basins. Overall, rocks in the basin dip to the border fault(Fig. 3).

Sedimentation patterns within the evolving extensional basins are controlled by complexly intertongued continental facies each related to their position in the basin(Fig. 4,5). Coarse-grained conglomerate of debris flow and alluvial fan origin are characteristic of facies along the most tectonically active edge of the half graben(Fig. 4,5). Clasts in the conglomerates are derived from Precambrian basement rocks and Paleozoic carbonates and clastics uplifted along faults on the margin of the basin. These facies grade basinward into nearshore-lacustrine siltstone and mudstone which grade into lacustrine mudstone and carbonate in the basin center. Typically the basin-center lake sediments grade back into nearshore facies and alluvial fans along the opposite basin margin. This margin is less fault controlled and may consist of a gentle unconformable surface on eroded Precambrian rocks(Fig. 4,5). Igneous rocks are interbedded with and cross-cut all the sedimentary rocks of the basin (Fig. 4,5).

HYDOCARBON ASSOCIATIONS:

A. Source rocks

Source rocks for oil and gas are present in the majority of the exposed Mesozoic basins(Table 2). Lacustrine black and gray shale and black siltstone and associated coal are typical source rocks. The total organic carbon content (TOC) (Table 2) for these rocks is well above the 1% that is considered the minimum for hydrocarbon source rocks(Tissot and Welte, 1984).

B. Thermal maturation

Thermal maturation patterns within individual basins, based on surface exposures, are highly variable (Fig. 6). Data are summarized in Table 3. Extensive igneous activity has caused local changes in the thermal maturation patterns and has coked many of the coals in the southern

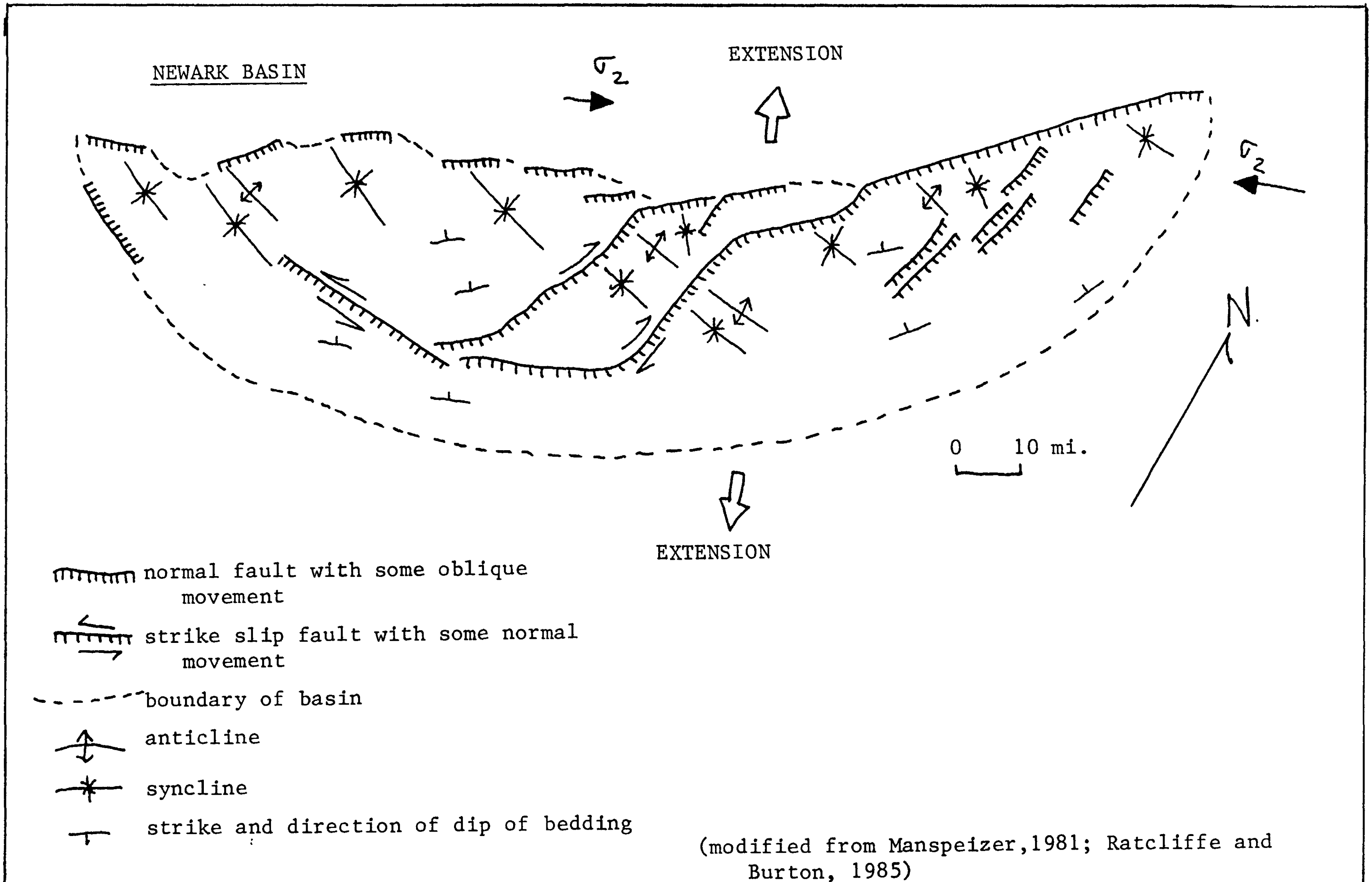


Figure 3. Generalized tectonic map of the Newark basin . Typical rift basin structures are shown and the inferred extension direction and location of intermediate principle stress direction sigma 2.

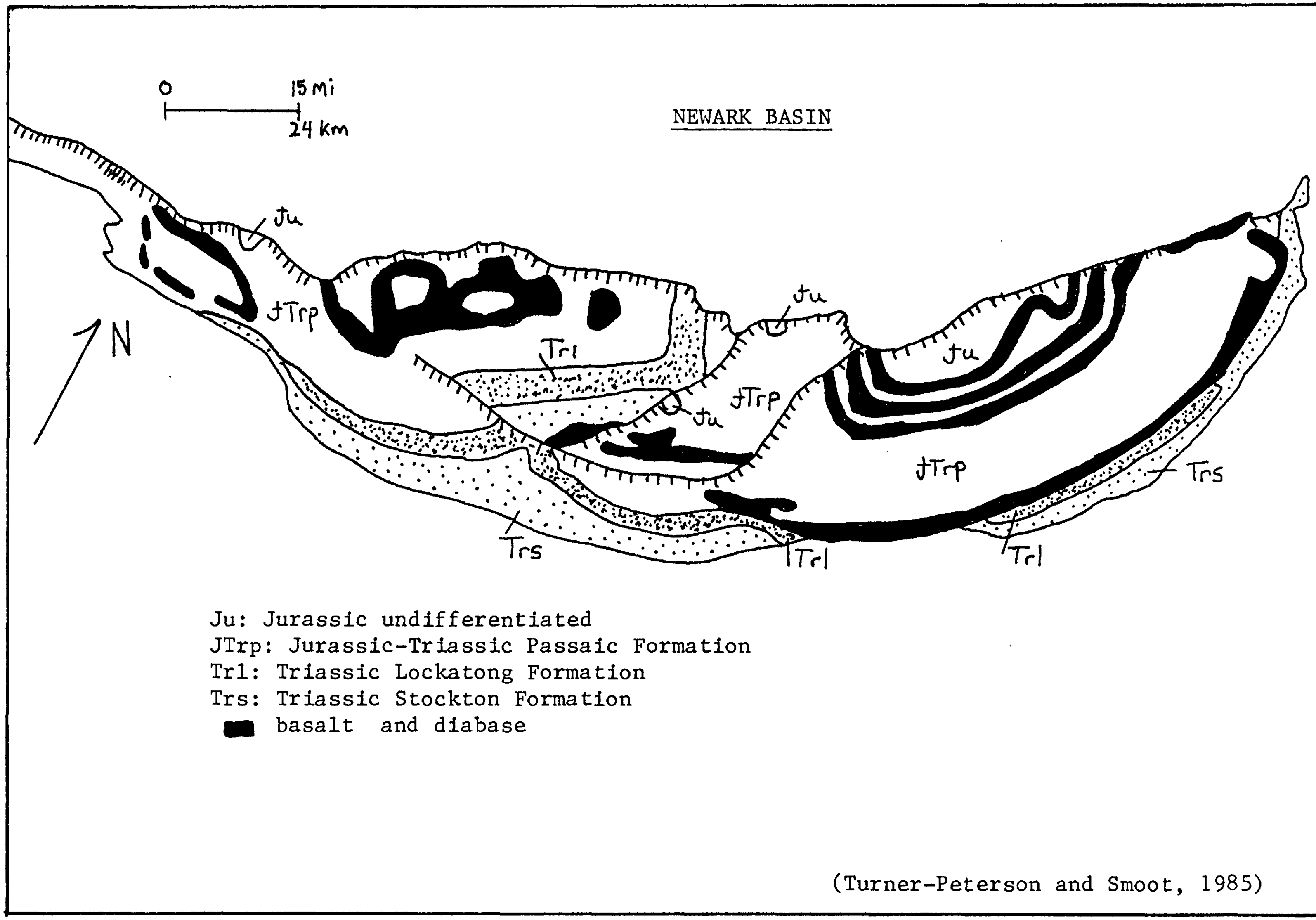


Figure 4. Generalized geologic map of the Newark Basin.

KEY:
1. Nearshore-lacustrine siltstone and mudstone; debris flows and alluvial fans on margin
2. Lacustrine mudstone and carbonate
3. Nearshore-lacustrine siltstone and mudstone
4. Fluvial-lacustrine sandstone; alluvial fans on basin margin

NEWARK BASIN

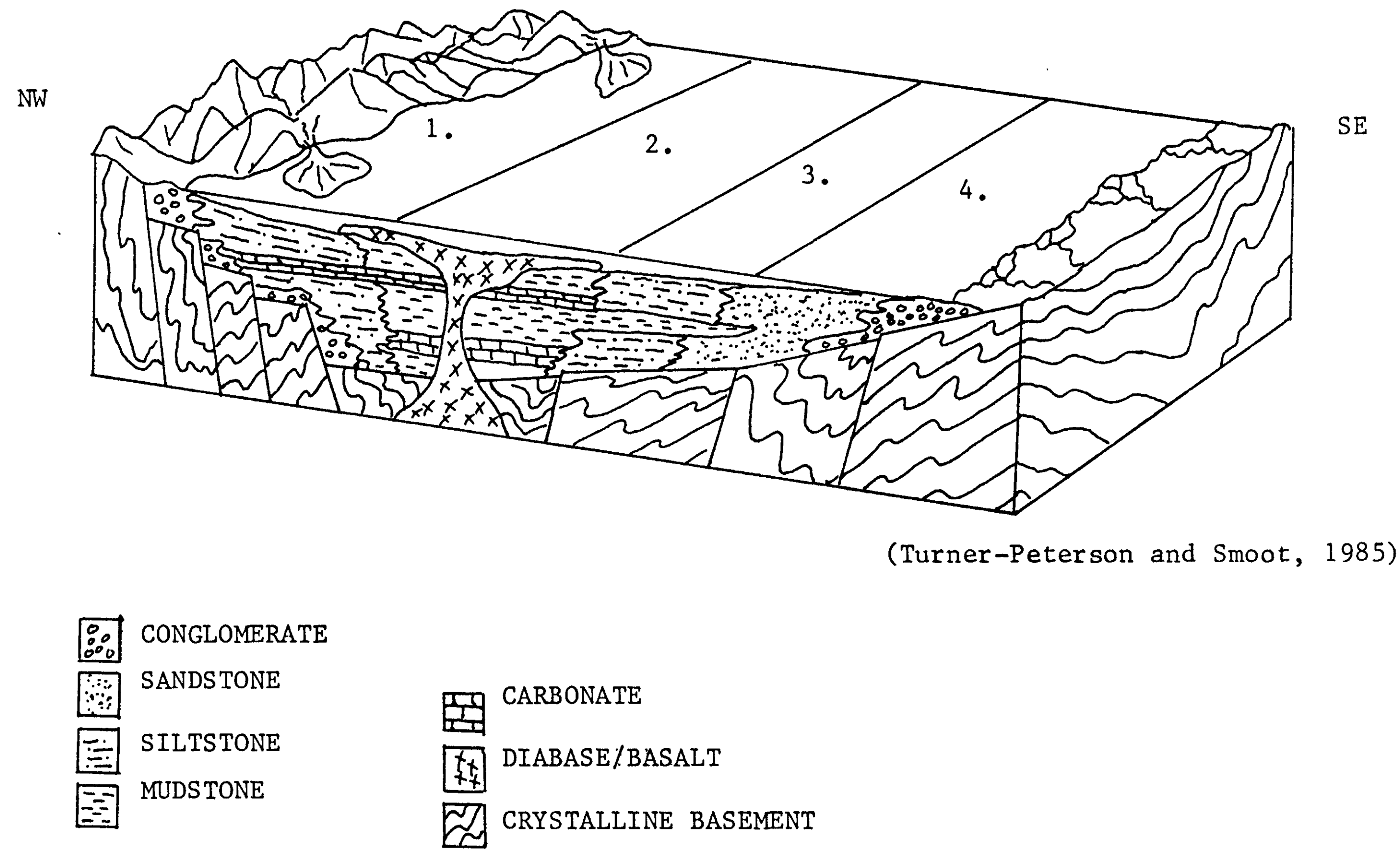


Figure 5. Generalized northwest-southeast block diagram showing distribution of facies in Newark Basin (modified from Turner-Peterson and Smoot, 1985)

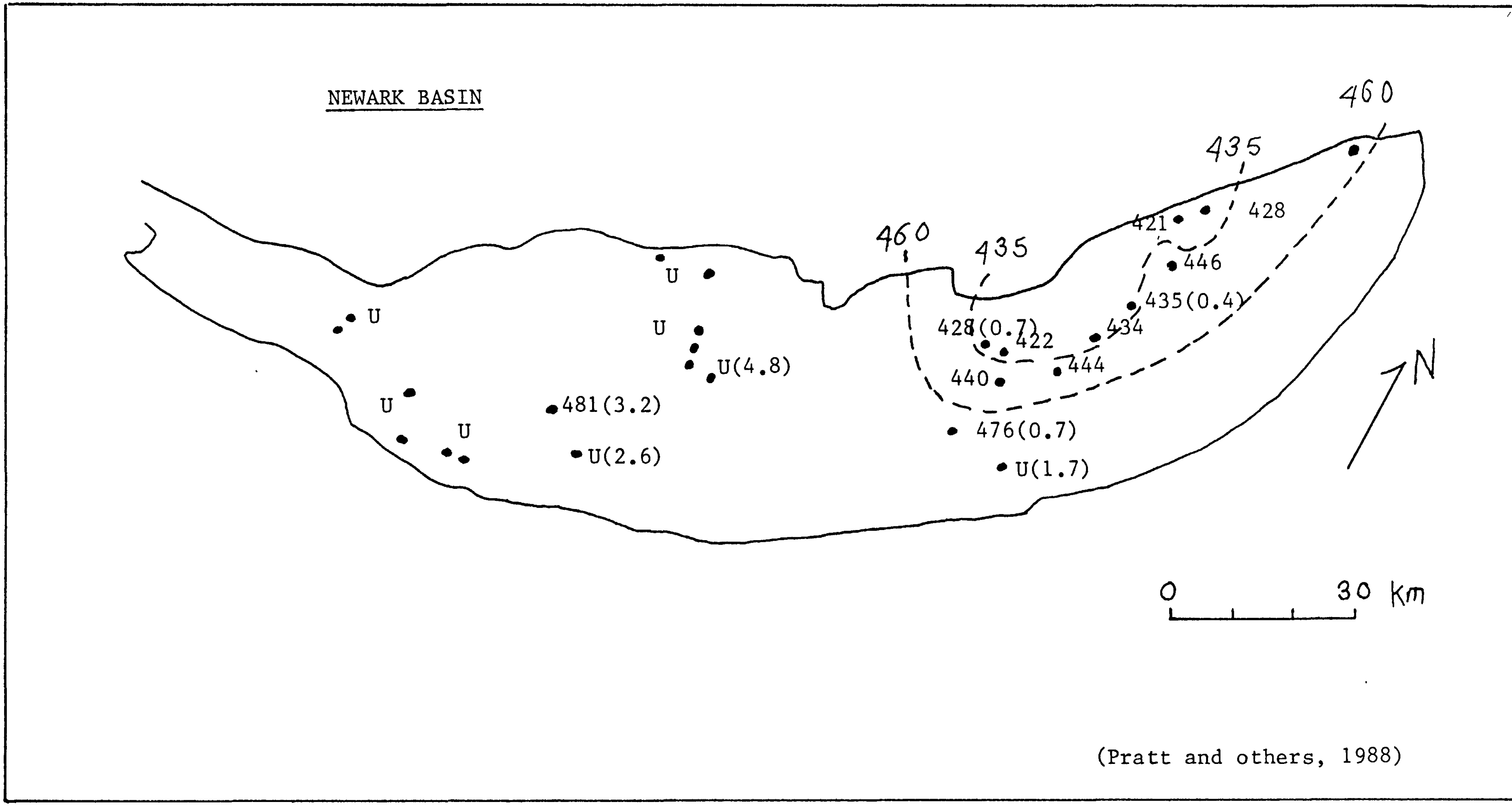


Figure 6. Thermal maturation in the Newark Basin. Map of locations for black and gray shale sample locations and thermal values. Temperatures in Fahrenheit of maximum pyrolytic yield (T max) are next to locations. Mean reflectance values in percent Ro are indicated by numbers in parenthesis. U indicates that Tmax values could not be determined due to low yield of pyrolytic hydrocarbons. Map modified from Pratt and others, 1988.

TABLE 1

Areas of exposed and inferred (below Coastal Plain sediments) Mesozoic basins and thickness of sedimentary rocks in the basins (Manspeizer, 1981).

BASIN	Miles^2	Km^2	Thickness (meters)
Exposed: (Piedmont and Blue Ridge Provinces)			
Hartford	1584	4104	3945
Newark	3136	8124	7505
Gettysburg	1105	2863	8960
Culpepper	1225	3174	6800
Danville	392	1016	3000
Dan River	1266	3280	3200
Richmond	200	518	1140
Taylorsville	24	65	1670

Inferred: (Coastal Plain)

Total inferred 33,800 mi 87,540km thickness unknown

Total area of the play is 42,732 mi (110,684 km)
Total federal lands is 2000 mi (5000 km)

TABLE 2

Source rocks in eastern Mesozoic basins:

Basin	Source	Organic content	Kerogen type
Hartford	Lacustrine black shales	TOC- 0.4-3.5%	1,2
Newark	Lacustrine black shales	TOC- 0.5-6.0%	2
Gettysburg	Lacustrine black shales		
Culpeper	Lacustrine black shales	TOC- 0.4-8%	2
Danville	Black shale/coal	TOC- 0.1-2.4%	
Deep River	Black shale/coal	TOC- up to 35%	2
Richmond	Black shale/coal	TOC- up to 40%	1,2
Taylorsville	Black shale/coal		
Farmville	Black shale/coal		

*TOC= total organic carbon

Data from: Pratt and others, 1985; Pratt and Burruss, 1988; Pratt and others, 1988; Robbins, 1982; Thayer and Robbins, 1982; Ziegler, 1983.

TABLE 3

Thermal maturation in Mesozoic basins:

Hartford	sub-bitum. to high vol.bitum.; Tmax. 441. TAI 2.5(oil); Ro 0,5-1.0
Newark	Tmax. 426-443; TAI 3+ (gas)
Culpeper	high vol.bitum.
Danville	high vol.bitum. to anthracite; Tmax 400+; TAI 4.0 (gas); Ro 2.15
Deep River	high vol. bitum. to anthracite; Tmax 451; TAI 2.6-3.0 (oil)
Richmond	high vol. bitum. to anthracite; Tmax 455; TAI 2.6-3.0 (oil)
Taylorsville	high vol. bitum; Tmax 437
Farmville	bitum.

**(TAI are Geo.Chem. values)

Data from: Pratt and Burruss, 1988; Pratt and others, 1988; Robbins, 1982; Robbins and others, 1988; Thayer and Robbins, 1982;
Reinemund, 1955; Ziegler, 1983.

TABLE 4

Hydrocarbons and exploration status in Mesozoic basins:

Hartford	migrated bitumen on sandstone outcrops and in fractures, no drilling; Texaco seismic surveys in late 1985.
Newark	migrated bitumen on sandstone outcrops and in fractures; Buck's Co. well 10,000 foot test to basement was dry hole(1985)
Gettysburg	4 dry holes; one well was 7,000 foot to Lower Cambrian clastics (1960s)
Culpeper	2 well with 2.5 barrels total recovered; bitumen on outcrops (1914,1916)
Richmond	approx. 15 holes from 1970s to present; both deep and shallow; oil and gas shows and some oil recovered.
Taylorsville	approx. 6 holes early 80s to present; tight holes but rumored to have oil and gas shows.
Deep River	early exploration of coal reported oil shales in black shales having 1.2-2.2 gals. oil/ton and black band with up to 15 gals. oil/ton and a total reserve estimate of about 271.000,000 gals. oil in basin; 1970s-1980s saw 3 tests, oil and gas shows with some oil recovered.
Farmville	one hole with oil and gas shows

Data source: McCaslin, 1985; Reinemund, 1955; Robbins, 1982; Ziegler, 1983.

basins (Reinemund,1955). Pratt and others,(1988) have shown that possible high heat flow was important in basin maturation.

C. Migration

Bitumen has been associated with outcrops in several of the basins and usually occurs in fractured sandstone (Pratt and Burruss,1988). Oil and gas shows in drill holes are evidence of continued migration of hydrocarbons. Kotra and others (1988) have recently characterized hydrocarbon geochemistry in the Hartford basin, and summaries of hydrocarbon types (Table 2) are found in Pratt and others(1985).

D. Reservoir rocks and traps

Little is known about reservoir rock characteristics. Possible reservoirs in the basins are sandstones of marginal lacustrine-deltaic, shallow lacustrine,and alluvial fan origin and other fractured shales and sandstones (Ziegler,1983). Sandstone with up to 20% porosity and 0.1-14 millidarcys permeability have been reported(Ziegler,1983). Traps in the basins are faults, anticlines and stratigraphic pinchouts (Figs.3,4,5). Rocks in the Mesozoic basins may be better sealed below the cover of Coastal Plain sediments.

E. Exploration

Although exploration in the exposed and inferred basins has occurred for almost 70 years (Table 4) no commercial producing wells have been completed in them.

SUMMARY OF MESOZOIC PLAY:

The Eastern Mesozoic Basins have a viable hydrocarbon potential. Source rocks are present in most of the basins and these rocks have proven TOC values consistent with known source rocks elsewhere. Thermal maturation levels are well within the range of temperatures reached for oil and gas generation. Thermal maturation patterns may be complex and are a product of high regional heat flow, alteration by igneous activity and burial. Oil and gas shows and bitumen in fractures attest to generation and migration of hydrocarbons. Traps are present in most of the basins and are structural and stratigraphic. Traps in the basin rocks below the Coastal Plain sediments may be more favorable than in the exposed basins because of better seals. Little data on reservoir characteristics suggest favorable porosity and permeabilty. To date, there is no commercial oil and gas production in rocks of the Eastern Mesozoic basins. However, oil and gas shows have been reported and exploration is active.

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