sissippian or Early Pennsylvanian time from a gentle downwarp into a deep, relatively narrow trough with steep, commonly faulted sides, growing progressively as it received up to 5,000 feet or more of sediments of Atoka, Morrow, and possibly Springer (Goddard?) ages.

The Atoka and Morrow boundaries are indefinite on the basis of present knowledge. Some geologists place the top of the Atoka at the base of the Davis Sand (Grayson County, Texas). The writer has placed the top at an oölitic limestone (Lester?) midway between the Baker and Davis Sands. Westheimer believes the "micaceous sand" in the Ardmore basin Dornick Hills correlates with the micaceous Hartshorne Sandstone of the Arkoma basin and the Davis Sand of Grayson County. The sandstone correlated as Davis or "micaceous" in the Southeast Marietta field is several hundred feet higher stratigraphically than the Davis Sand of Grayson County.

A thick section of pre-Atokan appears northward as well as eastward from the mid-basin ridge. This is believed to be mostly Morrowan-lower Dornick Hills, Springer (Goddard?), and Caney. The boundaries are indefinite and based on electric-log characteristics, related to early sample work. More qualified determinations are necessary in samples from later wells.

Post-Atokan Dornick Hills also thickens eastward and northward in Grayson County, but thins and disappears southwestward against the lower faulted margin of the Muenster uplift. The same components may be noted in the Des Moines or Strawn (Deese), although the thickening here may be more related to the development of the present Gordonville trough by foundering and filling during erosional destruction of the Ouachitas.

More intense folding and thrust faulting, even deep within the basin, complicate considerably the development of structure and stratigraphy because of the loss of section (a loss which is not the result of depositional factors).

3. HAROLD J. HOLMQUEST, JR., Mobile Oil Co., Midland, Tex.; ROBERT T. JOHANSEN, U.S. Bureau of Mines, Bartlesville, Okla.; AND HAROLD M. SMITH, U.S. Bureau of Mines, Bartlesville, Okla.

INTRODUCTION TO COMPOSITION AND STRATIGRAPHY RELATIONSHIPS OF PERMIAN BASIN OILS, TEXAS AND NEW MEXICO

The present Oil Study Committee of the West Texas Geological Society was organized to study the oil composition and related stratigraphy of six projects in the Permian basin. These projects include the Simpson, Pennsylvanian, Wolfcamp, Abo, and Yeso rock units, and the multipay field study. Crude oils and associated water samples were analyzed by the U.S. Bureau of Mines Petroleum Research Center at Bartlesville, Oklahoma. Carbon isotope data were provided by the Sinclair Research Laboratory, Tulsa, Oklahoma.

Oil samples were distilled and the gasoline-gas oil part determined. The volume percent of paraffins (straight or branched chains), aromatics, and naphthenes (ring compounds) were derived for boiling fractions 1-7 (gasoline) and also of the aromatics for fractions 8-12 (gas oil). The carbon isotopic composition was determined for the high boiling fraction (+350°F). This composition is a function of the type of organic material deposited, the environment of deposition, and maturation history of the organic material. Data from Recent sediments show an increasing C^{13} isotopic composition from the rocks deposited in the terrestrial environment through those deposited in the open-marine, marine-carbonate, and marine-evaporite environments. Water samples were analyzed for pH, specific gravity, calcium and magnesium, sulfate, chloride, sodium, and resistivity.

Analytical data, including aromatic profiles, were used to group the oils based on elements of similarity. These groups were compared with isotopic composition and associated water data. Interpretation was based on the geologic history of the rock units involved in each project.

4. STEWART CHUBER, Consulting Geologist, AND ELTON E. RODGERS, Skelly Oil Co., Midland, Tex.

PENNSYLVANIAN—WOLFCAMP STUDY

Eighty-seven crude-oil samples were used in the Pennsylvanian-Wolfcamp study. Most of these were from carbonate reservoirs on the Eastern shelf and Horseshoe atoll.

Four geologic factors influence the Pennsylvanian-Wolfcamp crude-oil compositions: (1) the age of the shale envelope, (2) the paleogeography, (3) the migration history, and (4) the association with unconformities. Pennsylvanian shale envelopes yield crudes with low carbon isotopes. Local paleoenvironments have caused minor differences in the oil-generating character of the shales. Late migration or remigration into structural traps, and vertical mixing with pre-Pennsylvanian crudes in strato-structural fields, explain several distinct crude-oil types. Unconformity traps contain another type of Pennsylvanian crude which results from indigeneous generation and mixing with older crudes at the subcrop.

A classification of the Pennsylvanian-Wolfcamp crudes evolved from the use of carbon-isotope measurements in conjunction with the oil analyses. The classification appears also to be compatible with geological factors. The following groups are recognized:

Group	*Geologic Interpretation*
Ia	Penn. envelope, late structural accumulation, NE shelf
Ib	Penn. envelope, late structural accumulation, Central Basin platform
IIa	Penn. envelope, southeastern Eastern shelf
IIb	Penn. envelope, central Eastern shelf
IIc	Penn. envelope, north-central Eastern shelf
III	Wolfcamp envelope, primarily Horseshoe atoll,
IV	Penn. and Wolfcamp envelope, pre-Penn. unconformity assoc.
V	Penn. and Wolfcamp envelope, northern part of shelf.

5. ELTON E. RODGERS, Skelly Oil Co., Midland, Tex., BILL B. BELT, Gulf Oil Corp., Midland, Tex., AND ED H. McGLASSON, Mobil Oil Co., Midland, Tex.

OILS FROM YESO RESERVOIRS AND THEIR BASINAL EQUIVALENTS

Yeso rocks contribute a high percentage of the oil produced in the Permian basin. The Yeso was deposited as three distinct facies in late Leonardian time. The shelf deposits of slightly anhydritic dolomite are divided into the Glorieta and the upper and lower Clearfork rock units; the shelf-edge deposits around the basin margins consist of massive reef-like dolomite; and the basin deposits are predominantly shale, sandstone, siltstone, and limestone of the Spraberry Formation.

The basin sediments appear to be ideal petroleum source rocks and limited fracture development restricts the occurrence of basin oil to rock of Permian age. Shelf or platform oil may be mixed Permian and pre-Permian due to structural deformation, faulting, fracturing, and deposition across truncated surfaces.

Correlations of oil analyses with reservoir rock types suggest that differences in the chemical composition of basin and shelf oils may be related to the amount of evaporites in the reservoir rocks.

Oil groupings can be explained geologically through differences in sources, environment, paths of migration, or mixing of oils.

6. N. A. SAX, Humble Oil & Refining Co., Midland, Tex., AND WILLIAM K. STENZEL, Marathon Oil Co., Findlay, Ohio

OILS FROM ABO RESERVOIRS OF NORTHWESTERN SHELF

Twenty-five crude-oil samples collected along strike, up- and downdip, and stratigraphically high and low along the 75-mi Abo reef trend in southeast New Mexico were analyzed chemically and isotopically. It was hoped that these analyses would show significant relationships with geologic phenomena and that conclusions might be made regarding source, migration, and accumulation.

Geologically the Abo reef trend is a narrow east-west belt of middle Permian reef and bank-edge dolomitized carbonates approximately 70 mi long and 1-3 mi wide. These rocks form the reservoirs in significant Abo fields such as Empire, Vacuum, Lovington, *etc.* Dolomite of the Abo overlies Wolfcamp limestone. This dolomite-limestone interface is used commonly to separate rocks of Wolfcamp age from those of Leonard age; however, present evidence indicates that at least part of the subsurface Abo is Wolfcamp in age. The intertonguing relations of back-reef, reef, forereef, and basinal facies exist throughout the extent of the east-west "reef" belt. Generally, it can be stated that Abo petroleum originated in the basinal facies, migrated to the forereef and reef facies, and was restricted from further updip migration by anhydrite cementation. This cementation was caused by seepage refluxion on the shelf at the shelf-reef interface; anhydrite cementation decreases into the reef.

The analyses showed that the crude samples taken from Permian Wolfcamp, Abo, and Yeso reservoirs could be separated into three major source groups: Abo-Wolfcamp basinal rocks, Yeso basinal rocks, and pre-Pennsylvanian rocks. It has been demonstrated that crude-oil analyses and carbon-isotope analyses are excellent tools that can be used to determine the age of the source rocks of the Abo oil and enable the geologist to make significant conclusions regarding origin, migration, and accumulation.

7. B. B. COESTER, Atlantic-Richfield Co., Midland, Tex., AND JACOB L. WILLIAMS, Phillips Petroleum Co., Midland, Tex.

RELATIONSHIPS OF OIL COMPOSITION AND STRATIGRAPHY IN MULTIPAY FIELDS

Oil and water samples were collected and analyzed from five fields in West Texas and New Mexico. Two of the fields, Harper and Midland Farms, were "protected"; *i.e.,* the producing formations are not connected by known faults or unconformities and the oils from separate formations are different. Both protected fields are uncomplicated anticlinal traps.

Oil samples from Harper field from the Ellenburger (Lower Ordovician), Devonian, Pennsylvanian, and San Andres (upper Permian) are distinct. Simpson (Lower Ordovician) oil is identical with Ellenburger oil, showing a common source or migration *via* small faults.

At Midland Farms, Ellenburger and San Andres oils are distinct. Devonian and Silurian oils are similar to each other, because of a similar source, but are different from other oils. Pennsylvanian and Wolfcamp (lower Permian) oils also are similar to each other for the same reason, but are different from other oils.

Justis and Embar fields are "unprotected"; *i.e.,* some of the producing formations are connected by faults or unconformities and the oils in the different formations are similar. In both fields lower Permian rocks overlie lower Paleozoic strata unconformably. Both fields are faulted on the east flank.

At Justis, Ellenburger and Simpson oils are similar but not identical, possibly due to mixing from two sources. Montoya (Upper Ordovician), Silurian, and Clearfork (Leonard-Permian) oils are almost identical. This similarity may be due to a common source. It may also be due to migration, *via* faults, from preexisting Montoya-Fusselman pools to the Clearfork. Seven Rivers-Queen (upper Permian) oils are different from others in the field.

At Embar there are several transverse faults. At Block 11 field, 2 mi west of Embar, lower Permian rocks overlie the Devonian. The Devonian is absent on the crest of Embar, but is present and productive in downthrown blocks on the east flank. Ellenburger, Silurian, Devonian, and Clearfork oils at Embar are very similar due to migration from a common source or to migration *via* faults. Devonian oils at Block 11 are similar to but slightly different from oils at Embar.

8. JOHN E. GALLEY, Shell Oil Co. (Retired), Kerrville, Tex.

SOME TECTONIC PRINCIPLES IN PERMIAN BASIN OF TEXAS AND NEW MEXICO

The Permian basin of Texas and New Mexico is primarily a depositional feature. It occupies the site of a structural depression in the relatively stable continental interior of North America. All tectonic events that created the Permian basin and its internal elements took place during the Paleozoic.

The Central Basin platform is the most prominent tectonic element within the basin. Smaller uplifts associated with the Central Basin platform cluster on and around it. They include most of the oil- and gas-producing anticlines of this prolific province.

The Central Basin platform and many of its satellite anticlines are bounded by faults along their steeper flanks. Some of the faults are "normal," where categorized by the absence of expected strata in a well bore; others are categorized as "reverse" where a stratigraphic section is repeated in a boring. All known faults in the province are vertical or nearly so. There is no evidence of low-angle thrust faults north of the Ouachita-Marathon tectonic belt. There is no evidence that vertical movements on the faults were caused by lateral compressive forces of regional scope.

Evidence of strike-slip movement is inconclusive