

SHOEMAKER, WILLIAM A., Idaho State Univ., Pocatello, ID

Geology of Raymond Canyon, Sublette Range, Western Wyoming

Raymond Canyon is located on the west side of the Sublette Range, Lincoln County, Wyoming. The study area is just east of the Idaho border and 10 mi (16 km) southeast of Geneva, Idaho. It contains an ideal view of a thrust fault (Tunp thrust), excellent exposures of vertical strata, small-scale folding, and minor strike-slip faulting formed during development of the Idaho-Wyoming thrust belt.

Formations exposed range in age from Late Pennsylvanian to Tertiary (Pliocene) and include: the lower part of the Wells Formation (Pennsylvanian, total thickness 720 ft or 219 m); the upper part of the Wells Formation and the Phosphoria Formation (both Permian, 153-210 ft or 47-64 m); the Dinwoody Formation (185 ft or 56 m); Woodside Shale (540 ft or 165 m); Thaynes Limestone (2,345 ft or 715 m); and Ankareh Formation (930 ft or 283 m), all of Triassic age; the Nugget Sandstone (1,610 ft or 491 m), Twin Creek Limestone, Preuss Sandstone, and Stump Formation, all of Jurassic age; and the Salt Lake Formation and the Sublette conglomerate, both Pliocene postorogenic continental deposits. Generally these formations are thinner than in nearby areas to the west and northwest.

Raymond Canyon lies on the upper plate of the Tunp thrust and the lower plate of the Crawford thrust of the Idaho-Wyoming thrust belt. Thus, it lies near the middle of the imbricate stack of shallowly dipping thrust faults that formed in the late Mesozoic.

Study of the stratigraphy, structure, petrography, and inferred depositional environments exposed in Raymond Canyon may be helpful to those engaged in energy development in the Idaho-Wyoming thrust belt.

SINGDAHLSEN, D. SCOTT, Montana State Univ., Bozeman, MT

Structural Geology of Swift Reservoir Culmination, Sawtooth Range, Montana

Northwest-trending, thrust and folded rocks of Paleozoic and Mesozoic age comprise the Sawtooth Range of northwestern Montana. The Sawtooth Range is a part of the northern disturbed belt and is characterized by thin-skinned deformation. Stratigraphy plays an important role in the location and character of the various thrust sheets. Major decollement surfaces include the Upper Cambrian, the top of the Devonian, and several horizons within the Mississippian.

In the Swift Reservoir area, a broad culmination exposes Cambrian through Cretaceous strata in a series of imbricately stacked, west-dipping thrust sheets. The structural configuration of the culmination appears to be a compound duplex zone with structures north and south of Swift Reservoir dipping away from the culmination. Mapping of the culmination reveals vertical stacking of thrust sheets, and a lateral ramp that forms the southern boundary of the duplex. A structural high in the basement may have resulted in ramping of the thrust sheets and formation of the culmination.

Deformation within the thrust sheets is controlled by structural position and by ductility contrasts between the stratigraphic units. Deformation varies widely, ranging from tight overturned folds in the Cambrian units to broad open folds and fractures within the Mississippian. Because of the variation in lithology and ductility, the most intense deformation is observed within the Cambrian units. This deformation is characterized by overturning of folds in the direction of thrust transport, and the development of small-scale kink folds, cleavage, pencil structures, and boudinage.

SMITH, DERALD G., Univ. Calgary, Calgary, Alberta, Canada

Anastomosed River Deposits, Sedimentation Rates, Basin Subsidence, and Locations in Proximal Molasse Basins

Recent research on large sized modern anastomosing river systems (upper Columbia River, British Columbia, Canada, and Magdalena River, Colombia, South America) has recognized six depositional environments: channel, levee, crevasse-splay, lacustrine, marsh, and peat bog or swamp. Average sedimentation rates in both river systems are 5 mm/yr and 3.8 mm/yr, respectively. Such rapid sedimentation rates (vertical accretion) are keeping pace with equivalent rates of basin subsidence. High rates of sedimentation and basin subsidence are most likely to be

found at proximal locations in molasse basins during major orogenic pulses. Such conditions were present during the Columbian and Laramide orogenies during the early Cretaceous and Tertiary in the foreland adjacent to the Rocky Mountain system. Thus, channel and crevasse-splay shale-encased sandstone reservoirs and coal, common in anastomosed fluvial rock sequences in proximal molasse settings, should be encountered in parts of the Western Interior sedimentary basin. Such deposits probably have been interpreted as deltaic or alluvial plain and should be reexamined to better predict sandstone trends for hydrocarbon exploration.

SOBEL, LLOYD S., Pennzoil Co., Denver, CO

Submarine-Fan Complex in Late Precambrian Yellowjacket Formation, Central Idaho

A thick sequence of Late Precambrian metasedimentary strata exposed in central Idaho represents part of a submarine-fan complex deposited in the Yellowjacket basin where important strata-bound cobalt deposits have been found. Three distinct sedimentary lithofacies are recognized within the Yellowjacket Formation on the basis of bedding style and sedimentary structures. These facies represent the laterally extensive and progradational sequence of basin-plain, outer-fan, and mid-fan environments.

The basal member of the sequence is a graded argillite, deposited in a basin plain as hemipelagic mud, and as very thin, graded couplets of silt and clay. This facies was succeeded by a ripped quartzite, deposited as thin layers of sand and silt in the outer-fan environment. As the top of the sequence is a laminated quartzite, deposited as beds of fine sand in a mid-fan environment by nonchannelized turbidity flows and possibly reworked by bottom currents. The vertical sequence of facies is gradational and indicates a progressive shift toward higher energy conditions with time.

A comprehensive basin analysis is not possible because adequate paleodepth and paleocurrent indicators are lacking. However, several important features of the Yellowjacket basin can be determined. Turbidite deposition was continuous and began in deep quiet water and was accompanied by the slumping and sliding of waterlogged sediment. Continued progradation had a subsiding effect on the basin. The basin was part of a passive craton margin, receiving sediment from a mountainous area in gneissic or crystalline terrane located to the east or northeast.

SONNENBERG, S. A., Bass Enterprises Prod. Co., Denver, CO, and L. B. CONYERS, Devon Energy, Denver, CO

Tectonic and Sedimentation Model for D Sandstone Deposition, Zenith Field Area, Denver Basin, Colorado

Cretaceous sandstones are oil and gas productive throughout a large area in the Denver basin. The Zenith field is a recently developed area that contains significant reserves in the D sandstone. Minor production also comes from the J sandstone.

Detailed mapping of the D sandstone suggests that productive sandstones are of channel origin within a valley-fill complex. Trapping of petroleum appears to be mainly stratigraphic with structure playing a minor role.

The stratigraphy of seven Cretaceous stratigraphic intervals was analyzed to determine if paleostructure may have influenced D depositional patterns. Thickness variations within stratigraphic intervals are caused by unconformities, convergence, and normal faulting. Thickness variations caused by unconformities and convergence may be related to paleostructure; variations caused by normal faulting are postdepositional and related to Laramide structure. Analyses of seven stratigraphic intervals clearly show that paleostructure influenced D sandstone depositional patterns. A new model proposed for D sandstone deposition incorporates paleotopography and sea level changes. During or immediately after the deposition of the Huntsman Shale and a thin regressive D sandstone deposit, a structural low area formed. The low area was probably created by basement fault-block movement. Concurrent with the tectonics, a drop in sea level occurs which drains a portion of the D depositional basin. A drainage system develops and follows the low area and incises through the regressive D deposit and into the Huntsman Shale. A sea level rise occurs and thick D channel sandstones are then deposited within the

eroded valley. The present structure at the top of the J sandstone (stratigraphically older than the D sandstone) is a structural low in the area where D valley-fill sandstones occur. The trend and location of the low at J level are identical to the trend and location of the D valley-fill deposits. Thus, the present low at the J level confirms the paleostructure interpretation.

This new model for D sandstone deposition, incorporating paleogeography and sea level changes, provides a new idea for petroleum exploration in the Denver basin.

SPANG, J. H., and J. P. EVANS, Texas A&M Univ., College Station, TX

Basement Fault Configurations, Wyoming Province

For many basement-cored folds and related mountain flank faults in the Wyoming province, locally balanced cross sections can be constructed using structural relief and line lengths in the sedimentary cover rocks. By conserving the length of the upper basement surface, possible basement fault movement can be inferred. This faulting includes: (1) motion along a reverse fault which yields a folded upper basement surface, and (2) displacement distributed along a series of parallel basement faults. The sedimentary cover rocks are force folded and may be cut by mountain flank faults which place Precambrian rocks overlying either Paleozoic or Mesozoic rocks. Previously recognized thrusts, blind thrusts, rootless anticlines, and buckle folds in the cover rocks in adjacent basins are reinterpreted to represent thin-skinned deformation related to basement faulting. Where there is relative translation of the cover rocks, cross sections need not balance locally and the fault dips and basement geometries previously determined are in error. The fault dips calculated from locally balanced cross sections have been overestimated, and/or the displacement on the basement fault(s) has been underestimated. The displacement observed on mountain flank faults may be far less than the total displacement on the basement fault. In the simplest case, it may be possible to project the mountain flank fault down dip to infer the orientation and location of the basement fault(s) at depth.

SPRINKEL, DOUGLAS A., Placid Oil Co., Salt Lake City, UT, and GERALD L. WAANDERS, Waanders Palynology Consulting, Inc., San Marcos, CA

Correlation of Twin Creek Limestone with Arapien Shale in Arapien Embayment, Utah—Preliminary Appraisal

Striking and important stratigraphic patterns have emerged as a result of recent work during which members of the Twin Creek Limestone were correlated with the Arapien Shale, all of Middle Jurassic age. These correlations, determined first on the basis of electric and lithologic logs, are supported by recent palynologic work.

Three distinct dinoflagellate assemblages, assigned to the Bajocian(?), Bathonian, and Callovian stages, form the paleontologic basis for these correlations. The Bajocian(?) assemblage is found in rocks of the Sliderock and Rich Members of the Twin Creek Limestone. The Bathonian assemblage is found in units of the Boundary Ridge and Watton Canyon Members of the Twin Creek, and also in units of the lower Arapien Shale (lower Leeds Creek Member of the Twin Creek of Wyoming). The Callovian assemblage is found in rocks of the upper Arapien (upper Leeds Creek and Giraffe Creek Members of the Twin Creek of Wyoming).

Isopach maps, based on these correlations, indicate that most of central Utah was the site of a large marine embayment—the Arapien embayment—that was flanked on the west, south, and east by highlands. The maps also suggest that the ancestral Uinta Mountains, a submerged feature, affected sedimentation as early as Bajocian time, and became a significant barrier from the late Bathonian through Callovian. In central Utah, marine carbonates were deposited in the Arapien embayment during deposition of the Gypsum Spring through Watton Canyon Members of the Twin Creek Limestone. During deposition of the Arapien Shale, a major northward regression occurred; the embayment shrank to form a smaller basin—the Arapien basin—that lay directly south of the ancestral Uinta Mountains. Most of the Arapien Shale is shallow-water deposits, that formed in the basin under hypersaline conditions.

STAHL, STEPHEN D., and ROBERT C. SPEED, Northwestern Univ., Evanston, IL

Overstep Thrust Sequence Development in Winnemucca Fold and Thrust Belt, North-Central Nevada

The Sonoma Range lies at the western edge of the Winnemucca fold and thrust belt of north-central Nevada in which lower Paleozoic rocks are thrust westward over para-autochthonous Triassic shelf rocks that overlie Mesozoic autochthonous lower Paleozoic rocks. Evidence from this range indicates that the Winnemucca thrust sequence developed in overstep, rather than piggyback, fashion.

This assertion is based on fabric elements of the Triassic rocks and on the assumption that the style and attitude of a given fold reflect the relative proximity of thrusts at the time of formation of said fold. The data may be summarized as follows: (1) four generations of Winnemucca-age folds are recognized; all are west verging and show the same sense of asymmetry; (2) in succeeding generations, the apical angle of folds increases and axial planes change from nearly horizontal to nearly vertical; (3) also in succeeding generations, deformation becomes more penetrative, and shortening and hinge thickening decrease. If the Winnemucca thrust system were to have developed in piggyback manner, one would expect subsequent deformations to progress from open to tight folds, upright to recumbent folds, and little to much shortening, and to remain relatively uniform in degrees of penetrativeness and thickening in the hinge.

STEARLEY, RALPH F., and A. A. EKDALE, Univ. Utah, Salt Lake City, UT

Bioerosion in Rocky Intertidal Zone of Northern Gulf of California

Pleistocene sedimentary rocks exposed in the intertidal and shallow subtidal zones of the northeastern Gulf of California coastline are being significantly weathered and eroded by a diverse suite of biologic agents. Macroscopic bioerosion of carbonate substrates in this region is universal, although the distribution patterns of particular taxa of borers are patchy.

In the vicinity of Puerto Penasco (Sonora, Mexico), where the tidal range achieves a maximum of 9 m (30 ft), the dominant macroboring organisms include mytilid bivalves (*Lithophaga*), sipunculid worms (*Phascolosoma* and *Themiste*), and clinoid sponges (*Cliona*). Abundances are locally high (e.g., up to 120 sipunculids per 1,000 m³ of rock). Other prominent but slightly less abundant borers include bryozoans, regular echinoids, and polychaete annelids (eunicids, spionids, and possibly sabellids). Nestlers, which are organisms that occupy and sometimes modify or enlarge preexisting borings, are common. They include bivalves (mainly arcids and petricolids) and crustaceans (various crabs and shrimps).

Data on the distribution of borers with respect to intertidal microfacies are not sufficient to permit much generalization at this point in the investigation. However, it is clear that substrate character is an important factor. Poorly cemented beachrock (sandstone composed of bioclasts and volcanic rocks fragments) is bored intensely by bivalves and sipunculids. Limestone coquina is colonized by dense populations of boring bivalves and sponges. Loose shell material commonly contains borings of sponges and polychaetes.

To determine bioerosion rates and colonization sequences of boring taxa, experiments with marble slabs staked out at numerous sites are in progress.

STEVENSON, GENE M., Consultant, Denver, CO, and DON L. BAARS, Consultant, Evergreen, CO

Paradox Basin: A Model Pull-Apart Basin of Pennsylvanian Age

The Paradox basin of the east-central Colorado Plateau province is an elongate, roughly rhombic salt basin of Middle Pennsylvanian age. It is bounded on the northeast by the Uncompahgre-San Luis segments of the Ancestral Rockies. The writers have demonstrated previously that the