Windy River placer deposit at Red Mountain and inferred reserves at the Halibut Bay complex on Kodiak Island. Seventy less-accessible deposits in the remote western Brooks Range contain between 0.6 and 1.4 million tons of high-chromium chromite. The Rampart, Yukon-Koyukuk, and Alaska Range trends and the southeast Alaska region contain deposits with minor production potential.

FRITSCHE, A. EUGENE, California State Univ., Northridge, CA

Neogene Drape Folding Over Pre-Neogene Flexural-Slip Movements in Western Transverse Ranges, California

In several locations in the western Transverse Ranges of California are folded Neogene sedimentary sequences that unconformably overlie homoclinal sequences of pre-Neogene rocks. To accomplish the folding of the rocks above the unconformity without apparent deformation of those below the unconformity, a mechanism other than simple crustal shortening is required. It is proposed that differential flexural slip along bedding planes in the limbs of large-amplitude pre-Neogene folds produced drape folds of small amplitude in the unconformably overlying Neogene rocks. This drape mechanism implies that the Neogene rocks were folded while they were still in the soft-sediment stage and that they were lengthened parallel to bedding during the process. Procedures that use the length of folded beds to determine the amount of crustal shortening, therefore, may indicate a greater amount of crustal shortening than actually occurred.

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Seastacks Buried Beneath Newly Reported Lower Miocene Sandstone, Northern Santa Barbara County, California

Three large, isolated exposures of a light-gray, coarse-grained, thick-bedded sandstone unit occur in the northern San Rafael Mountains of Santa Barbara County, California. These rocks are moderately fossiliferous and contain *Vertipecten bowersi, Amussiopecten vanvlecki, Aequipecten andersoni, Otrea howelli,* shark teeth, whale bones, and regular echinoid spines. The fossils indicate that the sandstone unit, although previously reported as upper(?) Miocene, correlates best with the lower Miocene Vaqueros Formation.

This unit was deposited in angular unconformity on a Cretaceous, greenish-gray turbidite sequence of interbedded sandstone and shale, and onlaps the unconformity erosion surface from west to east, the unit being thicker in the west and older at its base. The underlying Cretaceous sandstone beds are well indurated, and during the eastward transgression of the early Miocene sea, they resisted wave erosion and stood as seastacks offshore of the advancing coastline, thus creating a very irregular topographic surface upon which the Vaqueros Formation was deposited. Some seastacks were as much as 4 m tall, as indicated by inliers of Cretaceous rock surrounded by 4-m thick sections of the Vaqueros Formation.

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Smectite Diagenesis in Bentonites of Shale Wall Member of Seabee Formation, North Slope, Alaska

The Upper Cretaceous Colville Group is present over much of the north-central North Slope and includes the Seabee Formation, a part of a progradational clastic wedge derived from the ancestral Brooks Range. The lower member of the Seabee Formation, the Shale Wall Member, contains thin to moderately thick bentonite beds. Biotite separated from bentonite from the Shale Wall Member in the northwestern subcrop area yielded K/Ar ages of about 92 Ma, dating the origin of these pyroclastic deposits as early Turonian. In the northern part of the National Petroleum Reserve in Alaska (NPRA) and in the vicinity of Prudhoe Bay field, the less than 2-millimicron fraction of Shale Wall bentonites consists predominantly of smectite with trace to minor amounts of kaolinite. Eastward along the Barrow arch, the depth of burial of the Shale Wall Member increases from less than 300 m in the NPRA to at least 3,855 m in the vicinity of Mikkelsen Bay as a result of downwarping of the Barrow arch and thick Tertiary deposition. At a depth of burial of about 3,600 m, the smectite-rich bentonites are replaced by rectorite, an ordered mixed-layer illite/smectite (I/S). With increasing depth of burial, the percentage of expandable layers in the ordered I/S decreases from about 45% to 20%. K/Ar dating of the ordered I/S phase places the time of formation in the mid-Miocene, in close agreement with predicted timing of clay diagenesis based on burial history/thermal gradient considerations.

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Effect of Geothermal Pore-Pressure Conditions and Natural Gas Composition on In Situ Natural Gas Hydrate Occurrences, North Slope, Alaska

The factors controlling the distribution of natural gas hydrates (solid compounds composed of natural gas and water) in the earth include mean annual ground temperatures, geothermal gradients, subsurface pressure conditions, gas composition, and pore-fluid salinity. A thorough analysis of the effect of these parameters on thickness and depth of hydrate stability zones has been conducted. A thermodynamic model has been used to compute depth and thickness of zones of stability of gas hydrates in 34 representative wells on the North Slope. Several well logs in these depth ranges have been analyzed to determine hydrate zone thickness, porosity, and hydrate saturation. In well log analysis, the hydrate presence has been indicated by the following evidence: increase in acoustic velocity, strong resistivity deflection, small spontaneous potential deflection, gas shown on mud log, oversized caliper increase in the neutron porosity, separation of long normal from short normal, and decrease in drilling rate. In several of these wells, multiple zones of hydrates have been detected.

In the Prudhoe Bay and Kuparuk fields, hydrates are expected to occur primarily in six stratigraphic horizons, mostly in an unconsolidated unit characterized by a poorly sorted sandstone and conglomeratic lithology. Detailed examination of the neutron porosity and sonic velocity responses within one hydrate horizon in six wells in Kuparuk field indicates an average porosity of 44% and hydrate saturation of 93%. Such information is extremely relevant to quantification of gas hydrate deposits.

GOLDFARB, RICHARD, DAVID LEACH, WILLIAM PICKTHORN, and MARTI MILLER, U.S. Geol. Survey, Denver, CO

Genesis of Gold Deposits in Chugach Terrane of South-Central Alaska—Evidence from Fluid Inclusions

Gold-bearing quartz veins occur in shear zones, faults, and joints within the Upper Cretaceous Valdez Group flysch in the Kenai and Chugach Mountains of south-central Alaska. The veins are regionally restricted to areas of medium greenschist-grade metamorphic rocks and are notably absent in lower and higher grade metamorphic rocks.

Fluid inclusion studies were conducted on samples of gold-bearing quartz from the Moose Pass, Hope-Sunrise, Port Wells, and Port Valdez districts. Ice and clathrate melting temperatures indicate that the ore-forming fluids had low salinities, ranging from 0 to 5-equivalent wt.% NaCl. These fluids contain appreciable amounts of dissolved gases, as shown by the nearly ubiquitous formation of clathrates during inclusion freezing and by the common presence of three-phase inclusions consisting of aqueous fluid, liquid CO_2, and vapor. Total gas content varies from essentially nondetectable to as much as 10 vol.%. Freezing measurements on the inclusion fluids show the gas composition to vary from nearly pure CO_2 to mixtures dominated by CH_4 and N_2. Inclusion data indicate minimum trapping pressures of 1.5 kbar and corrected homogenization temperatures ranging from 260°C to 330°C.

We believe that the gold-bearing veins represent pathways for the escape of metamorphic fluids during rapid uplift of the Chugach and Kenai Mountains. The veins are believed to have formed along hydraulic fractures or along dilated preexisting fractures, created when fluid pressure exceeded load pressure.

HARBERT, W. P., L. S. FREI, ALLAN COX, Stanford Univ., Stanford, CA, and D. C. ENGEBRETSON, Western Washington Univ., Bellingham, WA

Relative Motions between Eurasia and North America in Bering Sea Region

Knowledge of the relative motion of the North American and Eurasian plates during the late Mesozoic and Cenozoic provide insight into the observed timing and style of deformational events in the Bering Sea region. Periods of strong convergence between the North American and Eurasian plates (approximately 70-50 Ma, Maestrichtian to Paleocene) are correlated with compressional deformation between the Chukotsk Peninsula and northern Alaska and the initiation of development and movement along the Denali fault. The convergence also may be the cause of a previously proposed counterclockwise rotation of the Alaska Peninsula. Transform motion between these plates (approximately 50-37 Ma, middle to upper Eocene) correlates with subsidence of the Bering shelf and creation of a series of pull-apart basins (Anadyr, Amak, Bristol Bay, Navarin, Pribilof, and St. George) along the Bering margin. Slight compressive convergence from 37 Ma to present may be responsible for the anticlinal deformation of basin-filling sediments in the Anadyr and Khatyrka basins reported by McLean. A correlation between the velocities with which the two plates moved away from each other in the North Atlantic and the geometry of interaction in the Bering Sea region can be seen for most of the Tertiary.

HARRIS, ANITA G., U.S. Geol. Survey, Washington, D.C., H. RICHARD LANE, Amoco Prod. Co., Tulsa, OK, and I. L. TAILLEUR, U.S. Geol. Survey, Menlo Park, CA

Conodont Thermal Maturation Patterns in Paleozoic and Triassic Rocks, Northern Alaska—Geologic and Exploration Implications

The Paleozoic through Jurassic stratigraphic sequence in the Brooks Range consists of platform to intraplatform basin deposits 1-5 km thick. This comparatively thin sequence of heterogeneous lithologies was tectonically disrupted and shortened at least 600 km to form a stack of allochthons that were transported relatively northward and emplaced during the earliest Cretaceous. Thermal patterns in Paleozoic and Triassic rocks, based on conodont color alteration indices (CAI) from about 600 localities, show: (1) a gradual increase in thermal level from the northern margin to about 3/4 of the distance southward across the range (from CAI 1 to 5.5 and higher); (2) a belt of mixed high values (CAI 4.5 to 7) along the south border of the range; (3) thermal levels in surface and subsurface samples in the range related to tectonic burial and not to pre-thrust burial metamorphism; (4) the same CAI values in rocks above and below the Ellesmerian unconformity in the northeast Brooks Range; (5) an association of anomalously high CAI values with mineralized areas and plutonic rocks; (6) a few anomalously high CAI areas of unknown origin that deserve further study; (7) thermal potential of hydrocarbons (CAI = 4.5) only in the westernmost and northern margins of the Brooks Range; and (9) mineralization potential related to anomalously high CAI values in the southern Brooks Range.

Triassic through Mississippian rocks in wells on the north flank of the Colville basin show conventional burial metamorphism patterns within each well and from well to well. All rocks indexed have thermal potential for hydrocarbons (CAI = 1-4.5).

The geology of the Seward Peninsula appears to be a southwestern continuation of that in the Brooks Range. Most of the western one-fifth of the Seward Peninsula contains 4-5 km of unmetamorphosed platformal, dominantly shallow-water carbonate rocks of Early Ordovician through Devonian age having CAI values of 3-4. Eastward, these rocks are thrust onto a blueschist terrane of mafic volcanogenic and clastic deposits and mixed carbonate and clastic rocks of probable Ordovician through Silurian age. Adjacent to, and possibly infolded with, these rocks are metamorphosed shallow-water carbonates of Early Ordovician through Devonian age similar to the rocks of the westernmost Seward Peninsula. Conodonts from the metacarbonate rocks have CAI values of 5.5-7, indicating temperatures of 350-450°C that are consistent with blueschist metamorphism.

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Thermal Windows of Yukon-Koyukuk Basin, Alaska

Vitrinite reflectance values from two mid-Late Cretaceous sedimentary sections in the Yukon-Koyukuk basin are within the oil window when plotted on a time-temperature-reflectance nomogram. However, preliminary paleomagnetic studies in other areas indicate a higher temperature overprint. To establish a more consistent record of paleothermometry in the basin, over 500 paleomagnetic samples from 35 localities and 25 K-Ar dating samples were analyzed. The samples include cobbles from conglomerates to test for remagnetization and argon loss.

Our analysis indicates that (1) some sample localities fail the conglomerate test (cobbles show consistent magnetic directions) and have experienced temperatures of 300°-500°C, (2) other localities, along the lower Yukon River, display primary paleomagnetic signals that pass both conglomerate and regional fold tests and have reversals, and (3) K-Ar ages of detrital components (volcanic pebbles and muscovite) from the lower Yukon River localities are older than their age of deposition, suggesting that temperatures have not exceeded the K-Ar blocking temperatures of these components (~ 300°C for muscovite and lower for whole rocks).

The complex thermal history of the Yukon-Koyukuk basin is a result of at least three magmatic episodes. The overprinted areas are closest to igneous occurrences; other areas were thermally unaffected by these widespread magmatic pulses.

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Brooks Range and Eastern Alps: A Tectonic Comparison

A comparison of the tectonic evolution of the Brooks Range (BR) and the Eastern Alps (EA) reveals a remarkable parallelism. Both of these Mesozoic-Cenozoic orogenic belts are underlain by sialic crust formed in an earlier Paleozoic orogenic cycle. The old basement is revealed in major tectonic windows: the Tauern Fenster (EA) and the Doonerak Window-Schwatka Mountains (BR)—which are unconformably overlapped by transgressive, neritic marine clastic to carbonate successions—the Permo-Triassic through Hochstegenkalk sequence (EA), and the Kekiktuk-Kayak-Lisburne sequence (BR). These successions are passive-margin sequences that pass southward, in palinspastically restored cross sections, to synchronous deep-water facies deposited on ophiolitic basement—Bunderschiefer on Triassic-Jurassic ophiolites (EA) and Kuna facies or Etivluk sequence on upper Paleozoic ophiolites (BR). Onset of subduction-collision is marked by olistostromal facies—Cretaceous wildflysch (EA) and Jura-Cretaceous Okpikruak Formation (BR)—and the development of major flysch-molasse successions in the foreland basins of the collisional fold and thrust belts.

Important major contrasts between these two mountain ranges reside in their colliding blocks and their post-orogenic histories. Alpine orogenesis was driven by continent-continent collision, closing out a young, narrow ocean, whereas Brooks Range deformation appears to have originated by arc-continent collision, closing out an older, broad (?)ocean. Younger Cenozoic deformation is extensional and strike-slip in the Eastern Alps, producing disjunctive basins, but Cenozoic deformation in the Brooks Range is diverse and includes compression in the east and extension in the far west.

By means of numerous stratigraphic and structural analogs in the better known Eastern Alps, the comparison of these two mountain belts provides interpretive insight into the Brooks Range.

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Early Electromagnetic Soundings in Permafrost Sections on North Slope, Alaska

During 1970-71, electromagnetic methods were used to determine permafrost thickness on the North Slope of Alaska between Barrow and Prudhoe Bay. In the measurements, the electromagnetic coupling between two loops of wire lying on the ground was measured over a frequency range from 20 to 8,000 Hz. An initial interpretation was done using graphical curve matching, but the data have been subsequently reinterpreted using a computer-based inversion approach. The results indicate that permafrost thickness, as indicated by high electrical resistivity in near surface rocks, is highly variable, ranging from 0 to 2,200 ft (0-660 m). The frozen rock has the least thickness and lowest resistivity in the deltaic areas beneath northward-flowing rivers. The effect may possibly be explained by the warming effect of the water flow in the rivers or by a change to finer grain size in the sediments in the deltaic areas.