analyze two projections of the time surface: one to a constant shot plane and one to a constant receiver plane. For each fixed shot or receiver, there is a distribution of time picks. Comparisons with real data distributions show a good match to theory as the time surface is manipulated. The study of these projections enables us to derive criteria for estimating the accuracy, precision, and consistency of any solution to the statics problem for the simple model of a linear refractor and high frequency statics. In this case the specific criteria are: (1) the expected value of each distribution is constant along each axis, (2) the variance of each distribution is zero along both shot and receiver axes, and (3) the shot and receiver statics are equal.

In addition, several basic types of anomalies can be recognized by their effects upon the first-arrival time surface. These basic types are: (1) geometric variation in the refractor, (2) velocity variation in the weathering, and (3) velocity variations in the subweathering. The combination of these three is a complete description of the general weathering statics problem.

The effects of these anomalies may be studied via the shot and receiver projections. Type (1) can lead to a blurring of the first-arrival time distribution. Type (2) can lead to a lens shape within the first-arrival projections. The lens is formed by a splitting of the left-hand and right-hand shots. Since the lens is composed of both time-rise and time-fall segments, it will be split under certain circumstances. Type (3) can appear as a change in the trend of the projections and a discrepancy between shot and receiver statics.

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## Provenance and Depositional Mode of Upper Cretaceous Chatsworth Formation Conglomerates, Simi Hills, California

Conglomerates of the Upper Cretaceous Chatsworth Formation occur as lenses of concentrated clasts in channels and as clasts dispersed at the base of thick, coarse-grained, graded sandstone beds. The matrix of the conglomerates consists of grains ranging from silt to granule size (4 mm) and comprises between 20 and 78% of any one conglomerate unit. The matrix composition ranges from 30 to 80% quartz, 25 to 60% feldspar, and 5 to 20% lithic fragments, with accessory biotite up to 5%. The conglomerate clast population is composed principally of clasts in the pebble size range. Five distinct rock types are recognized within the conglomerate clast population: blue-black argillite, 4 to 20%; felsic volcanites, 4 to 28%; felsic plutonites, 16 to 24%; arkosic sandstones and siltstone, 0 to 12%; and a group of genetically related quartz-rich clasts, 17 to 46%. The quartz-rich clasts include sandstones and siltstones with continuous textural gradation from well-preserved sandstone through partially recrystallized sandstone with sutured grains, into metamorphosed, foliated quartz sandstone and quartz schist types. In addition, a conglomerate unit may contain between 0 and 14% authigenic rip-up clasts.

The Chatsworth Formation, as a whole, is recognized to be a deep-sea fan complex upon which the primary depositional agent for sand was turbidity currents. Lenses of concentrated pebble conglomerates originated as debris flow, whereas beds of dispersed pebble clasts are of turbidity current origin. Paleocurrent data and the conglomerate clast composition for the Chatsworth Formation indicate that its detritus was derived from a source terrane to the south of the Simi Hills.

The Santa Monica Mountains basement complex contains a large mass of argillite and felsic plutonite, but contains no felsic volcanite or quartz-rich suite of rocks. The basement in the northern Peninsular Ranges includes representatives of the principal rock types recognized in the clasts of the Chatsworth Formation conglomerates and, therefore, it is the best possible choice for the provenance. Extensive Franciscan terrane also lies south of the Chatsworth conglomerates, but no Franciscan detritus is recognized in the Chatsworth Formation.

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## Cal Canal Field, San Joaquin Basin, California

Cal Canal is the northernmost of the 26 Miocene Stevens sandstone fields in the southern San Joaquin basin. Since discovery in 1977, at initial rates of 6,000 mcf gas/day plus 2,697 bbl of 41° condensate, the field has been fully developed and 17 wells are producing at sharply declining rates.

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## Upper Cambrian Stratigraphic Cycles, Southwestern Great Basin

One megacycle and numerous minicycles are recorded in the stratigraphic interval comprising the Dunderberg Shale and overlying Halfpint Member of the Upper Cambrian Nopah Formation in southeastern California and southern Nevada. The retrogradational leg of the megacycle is expressed by the succession: Bonanza King Formation (peritidal carbonate strata), Dunderberg Shale (outer ramp to peritidal shales and interbedded carbonates), and lower Halfpint (subtidal carbonates). The progradational leg is developed within the Halfpint, above the shale-carbonate boundary, as peritidal cryptalgal boundstone overlying subtidal shelf micrites and pelmicrites. Biostratigraphic data suggest this cycle is the result of regional transgression-regression. The Dunderberg-Halfpint contact, representing the boundary between shale and carbonate half-cycles within an apparent grand cycle, does not reflect a major shift in depositional environments, but rather the availability of terrigenous mud and the delicate nature of the carbonate "factory." The main environmental shift occurred during later deposition of the Halfpint carbonate lithosome when a peritidal algal thrombolite complex prograded seaward (see figure).

Coarsening-upward, meter-thick minicycles are abundant in peritidal and shallow subtidal facies in the Spring Mountains and Goodsprings, Nevada district and less common in more distal, deeper, outer ramp facies west of the Spring Mountains. Shallow-marine minicycles are expressed as micrite or shale, and occasionally cryptalgal boundstone, overlain by bioclastic packstone and grainstone as well as intraclastic beds. Deeper subtidal minicycles are expressed as bioclastic wackestone overlying shale or micrite. The minicycles are the products of fair weather-storm cyclicity on the open, deep to shallow subtidal ramp, as well as tidal influences within a peritidal algal-bank complex; as such they do not represent shallowing phases and shifting environments, but rather fluctuating conditions within their respective environmental settings.

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## Electro-Magnetic Oil Exploration Research Using Commensurate Frequency Phase Difference Technology

This paper defines and develops the characteristics of instrumentation that exploit the concepts of CFT (commensurate frequency technology), a modern application of frequency-domain electromagnetics. CFT instrumentation can operate in all modes (i.e., quasi-static, near field, or far field). In all modes, the phase difference between commensurate frequencies is measured to produce a signature relating only to geologic variations. Unlike classical EM measurements, which are apt to be dominated by near-surface features, the CFT process minimizes the effects of near-surface features by common mode rejection (CMR). This characteristic is clearly substantiated by comparison of CFT data and classical EM data.

"Phase" is an ambiguous subject that means different things to different people, and there are differences between phase sensitive detectors and phase meters. There are unique benefits and limitations to use of a phase meter.

Pioneering work has been done using GeoDecca instrumentation and the resulting data show that there is a distinctive, frequency-domain signature associated with a significant number of oil and gas fields in southern California. Recent work using GeOmega instrumentation shows that measurements of commensurate frequency phase difference are insensitive to near-surface pipelines that produce significant distortion of classical EM data taken at the same time and same place. Field data also show the signature enhancement that results when radio signals from four different directions are stacked to produce a composite signature. This will not surprise those who understand that the apparent electrical characteristic of the earth depends on the direction of arrival of electromagnetic waves. This complicates life and one might wish that it were not true, but field data clearly indicate the benefits of illuminating the earth with multiple frequencies from multiple directions.

The shallow skin depth of current GeoDecca (VLF) and GeOmega (LF) sensors is acknowledged. However, a question that cannot be answered at this time is "why the sensors produce a significant signature above a number of California oil fields where the oil and gas are commonly 10 or more skin depths in the earth."

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Closed-Basin Lithofacies in Upper Part of Esmeralda Formation, Clayton Valley, Nevada

The uppermost Esmeralda Formation in Clayton Valley, Nevada, consists of about 330 ft (100 m) of tuffaceous sediment deposited in a closed basin formed by Basin and Range normal faulting about 7 m.y. ago. Five closed-basin lithofacies can be defined on the basis of lithology and sedimentary structures: fluvial, debris flow, shallow lacustrine, spring, and playa. The fluvial lithofacies consists of light-gray to brown, trough-cross-bedded sandstone, lenticular clast-supported conglomerate, and irregularly bedded siltstone and mudstone. The debris-flow lithofacies is made up of pale olive-gray to white, poorly sorted, mud-supported conglomerate and gray sandstone, which commonly displays load structures and convolute bedding. The shallow-lacustrine lithofacies consists of white, light-gray, and greenish-gray, thin to medium-bedded, laminated mudstone, vitric tuff, and diatomite. The spring lithofacies is laminated travertine with convolute bedding. The playa lithofacies is made up of massive gray mudstone, reworked sandstone and siltstone, and mud-clast conglomerate.

Further information regarding the depositional environment can be deduced from studying the petrology of the rocks. The tuff beds and tuffaceous sandstones contain clinoptilolite, opal-CT, and phillipsite as alteration products of vitric material. The laminated mudstone of the shallow-lacustrine lithofacies contains hectorite, calcite, gypsum, halite, clinoptilolite, and opal-CT, but the massive mudstones of the playa lithofacies contain no hectorite. It is concluded that the hectorite and calcite precipitated from alkaline waters in a shallow, spring-fed lake. During playa deposition, the alkaline environment disappeared either as a result of increasing salinity or the deterioration of the spring source.

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Recognition of Middle and Upper Pleistocene Marine Deposits in Downtown San Diego, California

Recent excavations in the downtown area of San Diego have exposed fossiliferous marine sands of middle and late Pleistocene age. Molluscan assemblages recovered from these sands can be grouped into two distinct faunas referred to here as the Broadway fauna (middle Pleistocene) and the "E" Street fauna (late Pleistocene).

Amino-acid racemization age estimates by K. R. Lajoie on shells of *Chione* from these faunas are 560,000 ±75,000 years B.P. and 250,000 years B.P., respectively. Both faunas possess a decidedly warm-water aspect and reflect protected littoral to sublittoral environments. The Broadway fauna contains several local biostratigraphic index genera including *Turritella gonostoma* Valenciennes, *Argopecten abietis abbotti* (Hertlein and Grant), and *Pecten vogdesi* (Arnold), that are not present in the younger "E" Street fauna.

Historically, all marine Pleistocene deposits in the San Diego area have been referred to as the Bay Point Formation. New evidence suggests that temporally, faunistically, and geologically distant units can be recognized within the local Pleistocene section.

The deposits containing the Broadway fauna and the "E" Street fauna occur in low-lying areas at or near sea level and appear to have been deposited in an earlier formed topographic depression. This is in marked contrast to other, younger Pleistocene marine deposits in the San Diego area which occur as thin veneers on elevated marine abrasion platforms (i.e., the Nestor Terrace and the Bird Rock Terrace).

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Basin Analysis of Miocene Mint Canyon Formation, Southern California

The nonmarine upper Miocene Mint Canyon Formation crops out in a broad southwest-plunging syncline within the Soledad basin, about 30 mi (48 km) north of Los Angeles, California, between the San Gabriel and San Andreas faults. The formation is comprised of fluvial and lacustrine deposits.

Clast counts and paleocurrent directions indicate that the fluvial parts of the Mint Canyon Formation were deposited in a broad westward-draining trough. The distribution of local basement-rock source areas indicates that the alluvial wash crossed the San Andreas fault in the general vicinity of Soledad Pass, near Palmdale. Clasts in the central part of the trough are predominantly of volcanic origin, and most are foreign to the area and have no known local source. They must have been derived from east of the San Andreas fault. Among the wide variety of volcanic-clast types within the Mint Canyon Forma-