1. SOME PHYSIOGRAPHIC ASPECTS OF SOUTHERN CALIFORNIA *

By Robert P. Sharp †

Southern California is a land of physiographic abundances, contrasts, and peculiarities. The wide range of geological materials and structures, the considerable differences in climatic environments, the host of geological processes at work, and the recency of diastrophic events are the principal factors responsible.

PHYSIOGRAPHIC DIVISIONS

Several good physiographic descriptions of southern California are available (Hill, 1928, pp. 74-101; Fenneman, 1931, pp. 373-379, 493-508; Gale, 1932, pp. 1-2, 8-10; Reed, 1933, pp. 1-23, 267-268; Hinds, 1952, pp. 63-108, 185-215), and it seems pointless to add another by regurgitation of the same material. Readers interested in the location, size, trend, and inter-relation of landscape features can determine this from a few minutes' study of figure 1 skillfully prepared by Charlotte Bjornsson.

Southern California comprises several well defined natural provinces, which are discussed in Chapter II, but the region can be even more simply divided into three major parts: (1) the coastal area between the sea and the environs of the San Andreas fault, (2) the triangular Mojave Desert block between the San Andreas and the Garlock faults, and (3) the Basin Range country north of the Garlock fault. Following brief statements on these major divisions, three selected physiographic topics are given more detailed consideration.

The Coastal Area. The principal subdivisions of the coastal area are the Transverse Ranges, Los Angeles Basin, Peninsular Ranges, and the Colorado Desert. The Transverse Ranges locally give a strong east-west grain to the landscape, which is confusing to visitors. The Los Angeles Basin, separating the Transverse and Peninsular Ranges, is a broad downwarp filled with Cenozoic marine and continental deposits. The Peninsular Ranges comprise an irregular and complex highland sloping westward toward the sea, and the Colorado Desert features a great elongated depression containing Imperial Valley and the Salton Sea. The continental borderland off southern California is composed of deep basins and submarine ridges and banks, which in size, arrangement, and trend strongly resemble the topographic features of the adjacent land (Shepard and Emery, 1941, p. 9).

The coastal area displays a host of interesting physiographic features and relations, prominent among which is a marked topographic unconformity (Willis, 1925, p. 677) between a late mature erosion surface and the youthful slopes incising it. Remnants of this feature are widespread, and it seems likely that they represent the same episodes of geological history, although this has not been definitely established. The late mature topography is termed the Sulphur Mountain surface in the Ventura region (Putnam, 1942, p. 751) and, less suitably, the Timber Canyon surface in Santa Clara Valley (Grant and Gale, 1931, p. 38). It developed rapidly on areas of relatively soft Cenozoic rocks after the middle Pleistocene orogeny and prior to late Pleistocene uplifts.

The Sulphur Mountain surface is probably younger than remnants of an erosion surface or surfaces of even more gentle relief on areas of older crystalline rocks (W. J. Miller, 1928, p. 199). Many of these remnants were formerly attributed to the so-called Perris or southern California peneplain (Dickerson, 1914, pp. 259-260; English, 1926, p. 64), but later work makes one wonder if there ever was a southern California peneplain. Dudley (1936) presents data suggesting that the Perris surface, a remnant of the southern California peneplain, is actually an exhumed feature and therefore older than a higher erosion surface preserved on the tops of nearby mountains. These relations are hardly compatible with the concept of a single widespread peneplain (Gale, 1932, p. 2).

Features in the Peninsular Ranges formerly attributed to an extensive peneplain (Ellis and Lee, 1919, pp. 37, 49) have since been the subject of opposing interpretations involving differences in the basic concepts of W. M. Davis (Bryan and Wickson, 1931; W. J. Miller, 1935, p. 1553) and Walther Penck (Sauer, 1929). Briefly stated, this involves the question of whether erosion surfaces of low relief at various levels are the dislocated parts of a single surface or local features actually formed at the different levels. Something of the same problem enters in the instance of the subdued upland of the San Bernardino Mountains (Mendenhall, 1907; Vaughan, 1922, pp. 323-324). Is this an up-faulted part of an extensive erosion surface covering much of the western Mojave Desert (Hershey, 1902, pp. 4-5; Baker, 1911, p. 365) or is it a feature of local development?

The suggestion is offered that not enough attention is given to the possibilities of local pedimentation on areas of granitic * rocks. Surfaces of low relief bounded by steep slopes can be developed rapidly with respect to local base levels upon such rocks in the climatic environment of southern California. The coincidence between lithology favorable to pedimentation and some, if not most, of the erosion-surface remnants formerly attributed to a single peneplain is noteworthy.

* Contribution No. 643, Division of the Geological Sciences, California Institute of Technology.

† Professor of Geomorphology, California Institute of Technology.

* Igneous rocks of acid to intermediate composition with relatively coarse granular texture are included under this term.

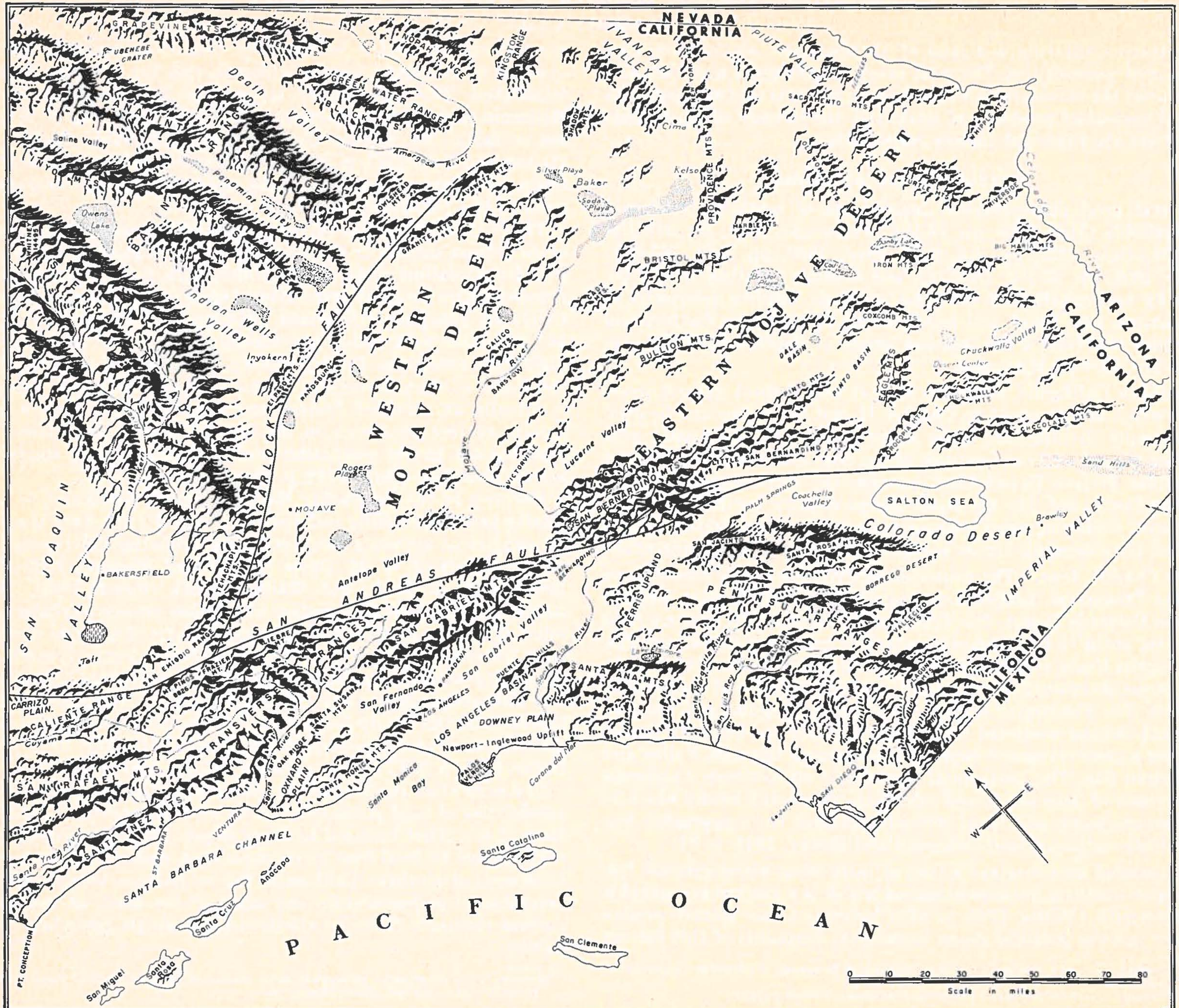

FIGURE 1. Physiographic diagram of southern California.

Within the coastal division the products of soil creep, earth flows, and landslides are widely seen on hill slopes underlain by Cenozoic sedimentary rocks, and this would be a good area in which to study the genesis and evolution of slopes on a wide variety of rocks and structures. A bare beginning has been made in this direction on slopes underlain by crystalline rocks (Strahler, 1950). The continental borderland off California provides excellent opportunity for investigation of submarine geomorphological features such as canyons (Shepard and Emery, 1941; Crowell, 1952), gullies, levees (Buffington, 1952), the continental terrace (Dietz, 1952), and many other features (Emery et al., 1952).

Mojave Desert. The north-south reach of the Mojave River separates the Mojave Desert into its two principal parts. The western Mojave is an area of predominantly low relief surmounted by a few isolated hillocks and low ridges. Davis (1933b, p. 245; 1938, p. 1359) considers it part of the Powell erosion surface, but this is one of those generalizations and oversimplifications that is difficult to establish or disprove by direct evidence. The area has unquestionably experienced much erosion, and it displays extensive surfaces of low relief on granitic rocks, but in the westernmost part it also includes wide flats underlain by alluvium. The eastern Mojave consists of mountains and basins which differ from the typical basin range topography by a lack of regularity in size, shape, and arrangement.

The Mojave country provides excellent opportunity for work on playas, alluvial fans, pediments, desert domes, relic and fossil soils, sand dunes, clay dunes, climbing dunes, falling dunes, yardangs, ventifacts, and the problem of eolian deflation. Desert varnish is widespread and deserves more extended study (Laudermilk, 1931), for its origin is not yet firmly established, and it may prove to have chronological value (Blackwelder, 1948). Casual observation also suggests that desert varnish may be a useful climatic indicator, for it appears to be deteriorating under present conditions in parts of the desert, possibly because of somewhat cooler and moister conditions following the post-Wisconsin xerothermic period.

Observers of desert forms do well to keep two principles in mind: (1) coarse granitic rocks are relatively non-resistant owing to their rapid disintegration, and (2) running water is remarkably efficient in the desert and contributes as much, perhaps more, to development of the landscape than it does in humid regions. This comes about because of the large supply of disintegrated debris available for transport, because of the concentrated nature of the runoff, and because the restraining influence of vegetation is small.

Basin Range Country. The region north of the Garlock fault, with its long narrow mountain blocks and corresponding basins, all trending in a northerly direction in classical basin-range fashion, differs markedly from the Mojave Desert to the south, and the boundary is sharply drawn by the fault (Noble, 1927, p. 35).

The Basin Range area provides good examples of upland erosion surfaces (Hopper, 1947, pp. 396-401; Maxson, 1950, pp. 101-103), geomorphic forms related to periodic uplifts of mountain blocks, fault scarps, fault scarplets in fans, some of the finest alluvial fans and cones in existence, extinct Pleistocene lakes (Gale, 1914; Blackwelder, 1933), and abandoned Pleistocene drainage courses (Hubbs and Miller, 1948, pp. 77-94; R. R. Miller, 1946). This area is also the home of the notorious wind-blown playa scrapers (McAllister and Agnew, 1948; Kirk, 1952; Clements, 1952; Stanley, 1953), and in Ubehebe Craters it possesses some of the finest dry maars on this continent.

THE ROLE OF DIASTROPHISM

A basic theme running through most of the major and many of the minor physiographic relations in southern California is Pleistocene deformation. This has been recognized in nearly all earlier physiographic treatments (Hershey, 1902, pp. 4-7; Mendenhall, 1908, pp. 14-15), but it deserves continued reemphasis. Faulting, folding, and warping have had a major hand in determining the size, shape, and arrangement of mountains and basins and even in some instances of ridges and valleys. With some exceptions, the principal functions of erosion and deposition have been to fashion details upon this diastrophically determined landscape.

Within the coastal area the middle Pleistocene orogeny is recognized as one of the most intense since the Jurassic (Reed, 1933, p. 273), and most of the principal landscape units were outlined or extensively modified at that time. Upfaulted, upfolded, and upwarped areas stand in relief not so much because they consist of resistant rocks, but because they have not yet been reduced by erosion. The belt of small en echelon domes and anticlines along the Newport-Inglewood uplift in the Los Angeles Basin affords good examples of folds so recently created that their present topographic form closely resembles the structure of the underlying materials (Hoots, 1932, pp. 27-29). In some instances alluvium is involved in this folding (Vickery, 1927, p. 423).

Diastrophism did not cease with the middle Pleistocene orogeny but continues to the present with the result that an impressive sequence of geomorphological developments is compressed into a remarkably short interval. For example, in the Ventura region the Sulphur Mountain surface was developed over a considerable area after the middle Pleistocene orogeny and then dissected in phase with repeated late Pleistocene uplifts separated by pauses during which terraces were cut along the sea and along rivers (Putnam, 1942, p. 751). The highest marine terrace now stands at an elevation of 1300 feet. A similar succession of events is known in the Palos Verdes Hills (Woodring, Bramlette, and Kew, 1946, pp. 113-117) and in southwestern Santa Barbara County (Dibblee, 1950, p. 19).

The desert region also displays considerable evidence of Pleistocene deformation. In the basin range country, recent fault scarplets break the alluvial fans at the foot of the mountain ranges (Noble, 1927, p. 39; Hopper, 1947, p. 398), and it is not difficult to imagine that Pleistocene faulting has played an important part in creating these ranges. In the Mojave Desert recent fault scarplets in alluvium are also common, but many of them are not closely related to the mountain blocks. This, plus the lack of consistent form and trend of the mountains, gives the impression that much of the present topography in the eastern Mojave is primarily the product of erosion acting upon a terrane of diverse rocks and complex structure. This focuses attention on the following problem.

Fully 60 percent of the eastern Mojave Desert consists of alluvium-filled basins about which almost nothing is known. Are these basins the product solely of erosion, solely of deformation, or a combination of both? Extensive studies of playa deposits in this area by the U. S. Geological Survey should eventually contribute to a solution of this problem. It is known that the alluvial filling in some, and perhaps most, of the basins is so thick that their rock floors are below sea level, and of course the same can be said for the surface of the alluvial fill in Death Valley. Thus, it is unlikely that these basins in their present form are solely the product of fluvial erosion. It is also difficult to imagine, in view of the alluvial filling, that eolian deflation has had much to do with creating the basins, although this has been advocated (Blackwelder, 1928). At some stage in geological history deposition has clearly exceeded erosion. This does not eliminate fluvial erosion as a possible and perhaps principal cause for the basins, but it requires a notable shift to deposition, to which climatic change may have been a contributing but not sole cause. Deformation must have played a part.

The evidences of recent faulting are so apparent in this area that the tendency is to think of faulting as the principal if not the only type of deformation. Warping is extremely difficult to detect in a region of rugged topography devoid of reference planes. However, in the region immediately east of Death Valley it is clearly recorded by Pleistocene lavas and fanglomerates and is one reason why Noble (1941, pp. 989-990) attributes a considerable part of the southern Death Valley depression to downwarping. Flexures are also recorded in late Cenozoic volcanics in the Ivanpah quadrangle mapped by Hewett (personal communication), and doming of an alluvial apron may be recognizable in the western Mojave (Wiese, 1950, p. 44). Other signs of warping were early recognized in the Mojave by Baker (1911, p. 367). Consideration should be given to the possibility that large erosional valleys in the Mojave region formerly draining to the sea have been deepened, dismembered, and subjected to alluvial filling by and because of warping just as much and perhaps more than by faulting.

A further word may be said about the role of warping in determining other topographic relations in southern California. It seems entirely likely that some of the highest and lowest parts of southern California mountain ranges mark the positions of broad transverse warps. In addition to features mentioned by Noble (1927, p. 32; 1932, p. 360) the San Gorgonio Peak-San Gorgonio Pass-San Jacinto Peak axis is directly aligned with the backbone of the Peninsular Ranges and may well represent a broad upwarp bearing slightly west of north. Reed and Hollister (1936, p. 96) remark on a somewhat similar relation extending into the Santa Ynez Mountains from the San Rafael Range, and Willis (1925, pp. 648-650) has called attention to arching in the California Coast Ranges.

PLEISTOCENE MARINE TERRACES

California marine terraces present a fascinating but difficult subject for study. They are well developed along the southern part of the coast from San Diego to Corona del Mar, in the Palos Verdes Hills, along the Santa Monica Mountains, in the Ventura region, and from Santa Barbara to Point Conception. As many as 15 to 20 terraces are recognized in some of these areas with elevations to at least 1600 feet above sea level. Most terraces have four principal features: (1) a sea cliff, (2) an abrasion platform truncating the bedrock, (3) a veneer of marine-laid detritus on the platform, and (4) a covering of terrestrial alluvium swept down from the highlands behind. This terrestrial coverhead attains thicknesses of as much as 150 feet and in places completely masks the topographic form of the terrace.

The greatest difficulty with terraces is the matter of correlation. This arises from the attempt to solve for two variables, namely eustatic shifts of sea level and deformation of the land, with only one known factor, the height of the terrace above sea level. Many of the earliest writings on California terraces ignored the possibility of eustatic shifts of sea level and attributed the terraces solely to uplifts of the land. The works of Davis (1933a, pp. 1044-1048) and Upson (1951, pp. 417, 444-445) clearly demonstrate the fallacy of this. Deformation of marine terraces has been recognized in the Palos Verdes Hills (Woodring, Bramlette, and Kew, 1946, p. 115), along the Santa Monica Mountains (Davis, 1933a, p. 1068), and in the Ventura region (Putnam, 1942, p. 739), but other parts of the coast are said to record no perceptible deformation of the terraces (Carter, 1950, pp. 93-95; Upson, 1949, pp. 108-112). Even local correlation of terrace remnants can be so difficult that reports of terrace deformation based on such correlations must be inspected with care. However, in the three areas listed above, deformation seems clearly established. In dealing with southern California marine terraces both eustatic and diastrophic influences must be considered; neither can arbitrarily be ignored. Furthermore, relations indicating whether a terrace was formed with respect to a stable, a rising, or a falling water level should be sought.

A common inclination in dealing with terraces is to think too much of the land features and not enough of the offshore relations. The latter are difficult to get at, but they are worthy of consideration since low-water stages may constitute at least half of the sequence along any coast. Some offshore cliffs, benches, and channels (Stearns, 1945, pp. 1072-1073; Upson, 1949, p. 108), and some onshore episodes of dissection (Ellis and Lee, 1919, p. 33; Upson, 1949; Carter, 1950, p. 92; Crowell, 1952, p. 66) are recognized and related to low-water stages, but more attention could be devoted to this matter.

To date, most terrace studies have consisted largely of measuring elevations above sea level. This is useful, necessary, and should be continued, but hopes for the future lie in giving more attention to the marine and terrestrial deposits mantling the terrace. Faunas in the marine deposits do not in themselves offer great hope of correlation (Woodring, Bramlette, and Kew, 1946, p. 105), but determinations of the absolute age of such organic remains may eventually provide a basis of correlation. Furthermore, the various phases of geological history recorded in the terrace deposits, especially the terrestrial coverhead, should aid in correlation. For example, a distinctive buried soil or marked episodes of channel cutting and refilling within the coverhead (Carter, 1950, pp. 92-101) may be recognizable in widely separated areas. Application of all the techniques of stratigraphy, geomorphology, and newly developed geochemical procedures bearing on geochronology and paleo-environments may eventually lead to successful terrace correlation.

The rewards will be considerable, for dated terraces can serve as time horizons over wide areas, and it should be possible to extend the chronology inland by means of river terraces. Properly correlated marine terraces can give an excellent measure of the amount and nature of late Pleistocene deformation along the coast and can contribute to an understanding of late Pleistocene geological events of all types.

ANTECEDENT STREAMS

Following Powell's (1875, p. 163) definition of an antecedent stream, the term was widely and indiscriminately applied to almost any stream transecting a ridge or mountain range. This loose practice and the discovery that the type example, the Green River across the Uinta Mountains, was not antecedent (Sears, 1924, pp. 282-304; Bradley, 1936, pp. 188-190) led to a reaction which too strongly discounted the principle of antecedence. The concept is sound, but air-tight cases of specific examples are extremely difficult to find. A suggestion (Vickery, 1927, p. 422), that the close association of oil fields and antecedent streams in southern California warrants a careful watch for such streams on the part of petroleum geologists, invites the comment that oil fields may be easier to prove than antecedent streams.

The recency of deformation in southern California makes this a favored area in which to "prove up" some antecedent streams. A number have been reported as shown by the following partial listing: Los Angeles River across Dominguez Hills, San Gabriel River across the Puente Hills and the Seal Beach structure, Santa Ana River across the Santa Ana Mountains, Verdugo Canyon across Verdugo Hills, Ventura River across Red Mountain fault, Zaca Creek across Purisima Hills, small streams across Wheeler Ridge, and many others (Vickery, 1927, p. 421).

In some of the instances cited, deformation is so recent that one is predisposed to accept antecedence. However, streams also can assume courses across uplifts by: (1) superposition, (2) headward erosion, (3) spilling across divides for one of several reasons, and (4) localization along transverse structures, as suggested for one of the supposed antecedent streams noted above (Reed and Hollister, 1936, p. 114).

Criteria for establishing antecedence are obviously needed, but they are not easy to obtain, and in some degree the approach is negative for it involves eliminating alternative possibilities. Criteria should be sought along the following lines: (1) close conformity between the amount and nature of the uplift and the present landforms, (2) topographic, stratigraphic, or other lines of evidence suggesting that the stream flowed in approximately its present path prior to at least part of the uplifting, (3) deformation of terraces, gravels, or other stream features along the antecedent course. Recognition of antecedent relations in streams can be most useful with respect to geologic history, especially as to the time and nature of deformation.

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