DAVID BLOOM

Magnitude of crustal extension in the southern Great Basin

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ABSTRACT

Strike-slip faults in the southern Great Basin separate areas of Cenozoic upper crustal extension from relatively stable tectonic blocks. Linear geologic features, offset along the Garlock fault, Las Vegas Valley shear zone, and Lake Mead fault system, allow reconstruction of the southern Great Basin to a pre-extension configuration. The Sierra Nevada, Mojave Desert, Spring Mountains, and Colorado Plateau are treated as stable, unextended blocks that have moved relative to each other in response to crustal extension, with the Spring Mountains held fixed to the Mojave block. Our reconstruction indicates a minimum of 65% extension (140 km) between the southern Sierra Nevada and Colorado Plateau.

INTRODUCTION

The amount that continental lithosphere may extend without (or prior to) the formation of oceanic lithosphere is of central importance to geodynamics, yet accurate determinations of large-scale intracontinental extension, constrained by several independent lines of evidence, are sparse. For example, the amount of Cenozoic extension in the Basin and Range province has traditionally been an extremely difficult quantity to constrain. Estimates of province-wide extension presented thus far in the literature range from 10% to 100% increase over original width, which corresponds to about 70 to 400 km of pull-apart in the northern Basin and Range province. Conservative estimates (10% to 30%) are based on assumptions of normal fault geometry in which stratal rotation is proportional to the amount of extension (Thompson, 1960). Assuming an average angle of 60° between faults and beds, the observed average tilt of 15° to 20° for late Cenozoic Basin and Range fault blocks led Stewart (1980) to deduce 20% to 30% extension for the entire province. It should be noted, however, that Stewart intended this estimate to apply only to extension related to the modern basins and ranges and not to events that predate their formation. Liberal estimates are based on three arguments. One is the relative crustal thicknesses between the Basin and Range province and the Sierran and Colorado Plateau provinces (Anderson, 1971b; Hamilton, 1978). Estimates ranging from 30% to 100% can be made if one assumes that the current 20 to 35 km Basin and Range crust was thinned from a crust as thick as the 40 to 50 km Colorado Plateau and Sierran crust. Unfortunately, actual crustal thickness in many areas of the Basin and Range is highly uncertain, and the pre-extension configuration of the Moho there can only be assumed. Another estimate is based on palinspastic restoration of Mesozoic paleotectonic elements of the Cordillera (Hamilton and Myers, 1966; Hamilton, 1969) which realigns the Sierran batholith and associated oceanic terranes with the Idaho batholith and oceanic terranes in western Idaho and eastern Oregon. This method yields roughly 50% to 100% extension for the northern Basin and Range province. A third estimate is based on the Cenozoic clockwise rotation of the western Cascades bracketed at 27° ± 7° by Magill and others (1981). They used a combination of paleomagnetic and geologic constraints to estimate 340 km (74%) extension in the northern Basin and Range and 210 km (140%) at the latitude of Las Vegas, Nevada. We feel that their analysis provides support in favor of a large amount of extension, but within the uncertainties of the constraints from which these figures were deduced, extension could have been as little as 210 km (36%) in the northern Basin and Range and 80 km (33%) at the latitude of Las Vegas. Problematically, Mankinen and Irwin (1982) and Craig (1981) have presented data that suggest smaller clockwise rotations of the Cascades (12° ± 11°) and Klamaths (12° ± 16°).

Perhaps the most accurate way of estimating extension is by restoring offset of linear geologic features across strike-slip faults that represent transformlike faults between areas of differential extension (Hamilton and Myers, 1966; Wright and Troxel, 1970) (Fig. 1). This method has been effectively used to quantitatively constrain minimum amounts of extension on a subregional scale (for example, Davis and Burchfiel, 1973; Guth, 1981). The favorable distribution of these structures across the southern Great Basin enables us to make an accurate minimum determination of extension across the entire province at the latitude of Las Vegas (Fig. 1A). Because this method is independent of assumptions implicit in the estimates based on normal fault geometry, large-scale paleogeography, crustal thickness, and paleomagnetic data, we feel that it provides an independent test of those estimates.

GARLOCK FAULT

Reconstruction of the western part of the transect is possible by matching correlative features across the Garlock fault. Left-lateral displacement on the Garlock fault, due to east-west extension in the Basin and Range province, appears to increase westward to a zone of maximum offset between the southern Sierra Nevada and the Mojave block (Hamilton and Myers, 1966; Troxel and others, 1972; Davis and Burchfiel, 1973). Correlation of the southern part of the Independence dike swarm north of the Garlock fault with dike swarms on the south side of the fault was first proposed by Smith (1962), who concluded that about 64 km of left-lateral offset had occurred since emplacement of the dikes in Mesozoic time (Fig. 1A). Smith and Ketner (1970) later proposed 48 to 64 km of left-lateral offset of the Paleozoic Garlock Formation. Finally, Davis and Burchfiel (1973) proposed that the Layton Well thrust, mapped by Smith and others (1968), is the offset equivalent of a thrust fault in the Granite Mountains 56 to 64 km to the east. These and other possible correlative features also discussed by Davis and Burchfiel (1973) constitute strong evidence for major left-lateral displacement.

Davis and Burchfiel (1973) proposed that the Garlock fault once continued at least 30 km to the east of its current surface termination at the southern Death Valley

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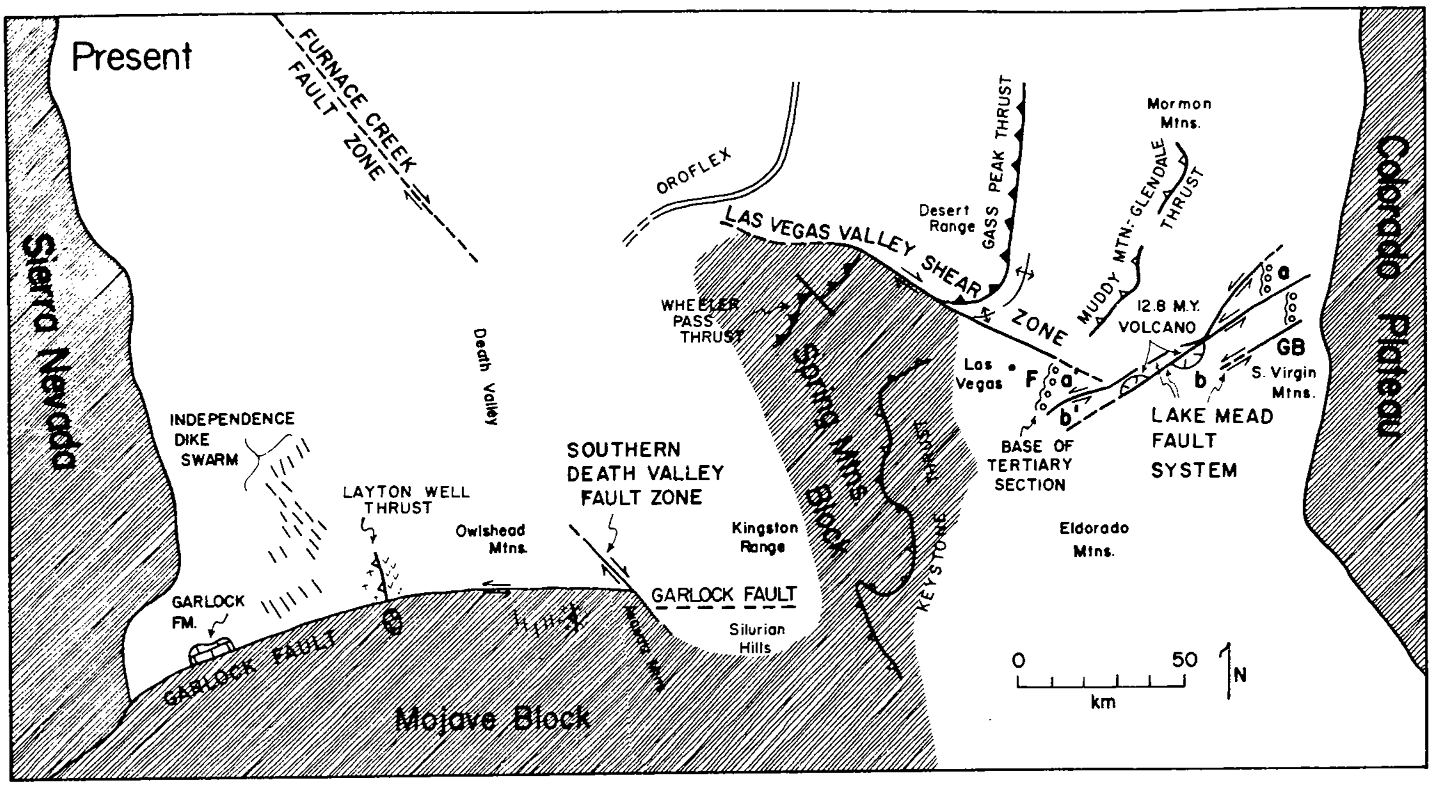
fault zone to a point of zero offset between the Kingston Range and Silurian Hills (Fig. 1A). According to this hypothesis, about 60 km of offset on the eastern Garlock fault was accommodated by extensional faulting across a terrane now 115 km wide. This terrane, encompassing the Owlshead Mountains, Kingston Range, and a broad, structurally complex intermediate area, must have undergone at least 100% extension. Recent unpublished mapping by Burchfiel and others has shown that the eastern part of the Kingston Range contains numerous low-angle normal faults and steeply tilted fault blocks, similar to the intermediate area (Wright and Troxel, 1973). Interestingly, the extended terrane ends to the south roughly along the eastward projection of the Garlock fault.

In Figure 1B, we have essentially followed the reconstruction of Davis and Burchfiel (1973), and we note that as long as crustal shortening south of the Garlock fault can be ruled out, our estimate of 60 km net crustal extension north of the Garlock fault is minimum.

LAS VEGAS VALLEY SHEAR ZONE AND LAKE MEAD FAULT SYSTEM

Reconstruction of the eastern part of the transect is made possible by matching features across the Las Vegas Valley shear zone and Lake Mead fault system (Fig. 1A). Right-lateral offset on the Las Vegas Valley shear zone was first postulated by Longwell (1960) on the basis of apparent eastward displacement of thrust faults that place Cambrian carbonates over Jurassic sandstones (Keystone–Muddy Mountain



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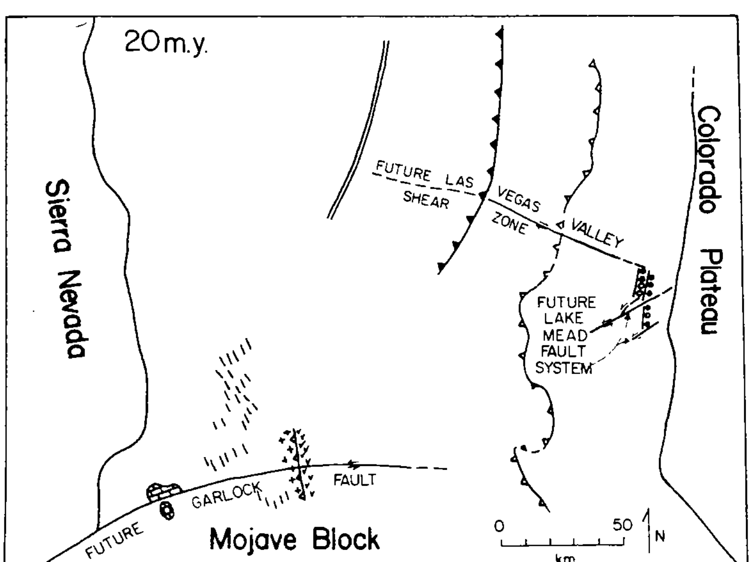

B

Figure 1. A: Map of strike-slip faults and offset geologic features in transect extending from Colorado Plateau to Sierra Nevada. Shaded areas are assumed not to have undergone major extensional faulting; unshaded areas include both extended and stable terranes. Fault movements can generally be modeled as result of movement between Colorado Plateau, Sierra Nevada, and Mojave–Spring Mountains block. GB = Gold Butte, F = Frenchman Mountain. See text for discussion. B: Fault reconstruction based on offset features shown in A, indicating about 140 km of net pull-apart with a component of southward movement of Sierras with respect to Colorado Plateau. See text for discussion.

system). Burchfiel (1965) showed that the shear zone did not exist as a surface rupture west of the northernmost part of the Spring Mountains block but was instead expressed by large-scale bending (termed an "oroflex" by Albers, 1967), which gradually gave way eastward to a discrete fault zone. He strengthened Longwell's estimate of offset by correlating the Wheeler Pass thrust in the Spring Mountains with the Gass Peak thrust north of the shear zone, suggesting an offset of about 23 km by surface breaking beneath Las Vegas Valley and an additional 21 km by bending. To this figure, Longwell (1974) postulated an additional 25 km of right slip due to bending of the Wheeler Pass thrust from a north-south to northeast strike, as observed in the structural grain of two lower thrusts (Lee Canyon and Keystone) in the Spring Mountains. These data, in addition to stratigraphic data summarized in Stewart and others (1968), indicate total displacement in the range 44 to 69 km.

The transform character of the Las Vegas Valley shear zone envisioned by Davis and Burchfiel (1973) and Liggett and Childs (1974) was examined in detail by Guth (1981). He observed that oroflexural bending in the Specter Range area was not as great as the offset of the Gass Peak–Wheeler Pass thrust, and he suggested that this difference in offset could be accommodated by extension north of the shear zone. His hypothesis is strongly supported by the surface geology, in which few extensional structures can be found south of the shear zone in the Spring Mountains block, but a broad terrane of steeply tilted Paleozoic and Tertiary strata are offset along low-angle normal faults north of it (Longwell, 1945; Guth, 1981). Guth further noted that the spacing between the Gass Peak and Glendale thrusts north of the shear zone is nearly identical to that between the Wheeler Pass and Keystone thrust to the south. The areas between the faults both north and south of the shear zone are devoid of structures suggestive of significant Tertiary extension, thus supporting the transform concept and indicating that these areas behaved as stable blocks during extension.

Offset on the complex Lake Mead fault system was first noticed by Anderson (1973), who documented a 20 km left-lateral offset of the 12.7-m.y.-old Hamblin-Cleopatra stratovolcano by one fault of the system, and he speculated on roughly 65 km of total displacement. In a study of Tertiary sediments in the Lake Mead region, Bohannon (1979) provided firm support of about 65 km of left slip on the system as a whole, on the basis of remarkable similarity between Frenchman Mountain (location F, Fig. 1A) and the South Virgin Mountains. This similarity includes (1) a distinctive stratigraphic sequence at the base of the Tertiary section (locations a and a′ in Fig. 1A), (2) gradual southward pinchout of identical Mesozoic formations beneath the basal Tertiary unconformity, and (3) the presence f distinctive monolithologic breccia sheets of Gold Butte rapakivi granite (Anderson, 1973; Longwell, 1974; now exposed in bedrock only in the South Virgin Mountains, location GB, Fig. 1A) in the Tertiary section at Frenchman Mountain. Consistent with Bohannon's figure, Smith (1981) provided data in support of a 40 km offset for one strand of the Lake Mead fault system by correlating the River Mountains stock just southeast of Frenchman Mountain with a compositionally similar volcano-plutonic assemblage in the northern Black Mountains (b′ and b, respectively, in Fig. 1A).

DISCUSSION

Conservative reconstruction of offset features along the strike-slip faults yields a total pull-apart of 140 km for the transect (Fig. 1B), which corresponds to a 65% increase in original width. This figure is based on the assumption that areas on the "stable" side of the strike-slip faults have not also extended. However, Dokka (1981) has mapped an area in the Mojave block which shows extreme northeast-southwest upper crustal extension between 21 and 16 m.y. ago, although the Mojave block immediately south of the Garlock has been tectonically stable relative to Pliocene and Quaternary extension in the Death Valley area. The Silurian Hills (Kupfer, 1960; Fig. 1A), just south of the projected trace of the Garlock east of the Death Valley fault zone inferred from geophysical data (Plescia and Henyey, 1982), contains extensional structures similar to those in the highly extended Death Valley region and may possibly represent large-magnitude extension, although the terrane south of the Silurian Hills between the southern Avawatz Mountains and the Spring Mountains block does not contain any significant extensional structures (Burchfiel and Davis, 1971; DeWitt, 1980). In any event, there is no evidence of significant crustal shortening anywhere south of the Garlock during extension.

Other areas of possible extension not accounted for in the reconstruction include the region between the Independence dike swarm and the Sierra Nevada, possible minor extension in the northern Spring Mountains block, almost certain extension between the South Virgin Mountains and the Colorado Plateau (see cross section on p. 115 in Longwell, 1945).

Since the sources of uncertainty seem to have the effect of increasing the estimate, we believe that 140 km is a reasonable minimum figure, corresponding to an increase in original width of about 65%. In light of the uncertainties, it is possible that the total extension is in the neighborhood of 80% to 100%. We believe this result lends considerable credibility to the other lines of evidence discussed above that suggest Cenozoic extension of the Basin and Range province on the order of a factor of two, as first deduced by Hamilton and Myers (1966). According to our analysis, the approximately 30(+) km crust characteristic of our transect (Smith, 1979) was at least 45 to 50 km thick following the Mesozoic Sevier orogeny. The configuration of the Moho at that time may have been similar to the modern-day Andes, in which the crust thickens as one moves from the Brazilian Shield into the back-arc thrust belt (James, 1971).

Because the crust in the northern Basin and Range province is currently as thin or thinner than the crust in our transect and because large areas of the northern Basin and Range have been shown to exhibit the same structural style as highly extended areas in our transect (for example, Armstrong, 1972), we believe that it has undergone a similar amount of extension and regard 60% to 80% (300 to 500 km) increase in width as likely.

The data discussed here also support geophysical studies of continental rifting which have recently found that extension of the continental lithosphere by a factor of two without forming oceanic crust may be quite common (McKenzie, 1978). It is now the task of geologists studying well-exposed examples of severe continental pull-apart to develop models of the cross-section geometry of upper crustal extension which are consistent with that deduced by other means. The widespread occurrence of Tertiary younger-over-older low-angle fault terranes throughout the Basin and Range (Young, 1960; Wright and Troxel, 1973; Moores and others, 1968; Anderson, 1971a; Armstrong, 1972, among the early workers) is highly significant toward this development. The interpretation of these terranes as large, rooted low-angle normal fault complexes (Wernicke, 1981, 1982; Wernicke and Burchfiel, 1982) geometrically analogous to (but not necessarily a reactivation of) thin-skinned compressional belts is one means by which large-scale extension may be expressed in the surface geology. The existence of such complexes suggests that large horizontal translations of rock masses may occur without significant stratal rotation—that is, terranes regarded as "stable" in our reconstruction may be underlain by large low-angle normal faults.

Although our purpose here has been to place a lower limit on total extension in a straightforward manner using reliable data on the amount and direction of strike-slip offsets, we remind the reader that the less straightforward task of relating the timing and kinematics of individual extended terranes to the strike-slip faults still lies ahead and will provide a further test of the arguments presented here.

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assumes that erosion rates have not greatly changed during the period in question.

First, all slopes that are being eroded must retreat. If the retreat is equal along all parts of the slope, then the retreat is parallel. If the retreat is greater on the high parts of the slope, then the retreat is called slope decline. Retreat is a geometric reality that is totally independent of our modest study.

Second, are our measurements representative of the spatial and temporal scales over which the processes operate? Many processes are ultimately driven by periodic events, or at least are recorded with periodic measurements. Smith seems to believe that by averaging the results of these discrete events we assume a continuous process with a constant erosion rate. An average rate does not mean a constant rate. An average is a statistic that is in general a reliable estimate of a random variable. Several reviewers objected to our use of data from seven caves rather than more extensive data from one cave. The collection of data from multiple sites was our best assurance that a catastrophic event at one site had minimal impact upon the outcome of the study. So, although little information exists on the spatial and temporal scales over which cliff retreat occurs in the Redwall Limestone, our average based on 13,000 yr of record collected from seven sites may be the best available data on rates of cliff retreat in the study area.

Smith is correct in his assessment that "it seems unlikely that sections of cliff above caves and overhangs can be considered representative of the cliffs as a whole." The sites studied are all in areas well away from streams or washes. This was essential in order that we measure the rate of cliff retreat independent of stream action. This intrinsic rate of cliff retreat corresponds to the mass wastage factor of Cunningham and Griba (1973). The sites were definitely not "sites where cliff retreat is, has been, or will ultimately be concentrated." Furthermore, the age of the caves, some of which probably originated on the Mississippian karst surface of the Redwall (McKee, 1976, p. 58), is irrelevant. Packrat middens are usually preserved only in dry caves, long after the cessation of cave-forming processes.

Last, have erosion rates been reasonably constant during the past 3.7 m.y.? This question is important in all geomorphic studies that attempt to calculate either a long-term result from a short-term rate or a modern rate from a long-term result. There is no way to ensure that retreat rates have remained constant during this period; however, the fact that our 13,000-yr-based average is from a time of Pleistocene climates adds credibility because this was the predominant climatic regime during the past 3.7 m.y.

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Comment and Reply on 'Magnitude of crustal extension in the southern Great Basin'

COMMENT

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In order to use bending and offset of correlative structures such as the Wheeler Pass and Gass Peak thrusts to determine magnitude of Cenozoic extension of the Great Basin as Wernicke et al. (1983) have done in their informative and thought-provoking paper, one must first demonstrate that such bending and offset occurred during Cenozoic time. I believe it is likely that the curvature and apparent offset of compressional features and certain Paleozoic isopach values that are used to measure offset on the Las Vegas shear zone occur in that position as a consequence of movement during late stages of thrusting in Late Cretaceous time.

Although the Las Vegas shear zone was first postulated by Longwell (1960) to be a product of Mesozoic thrusting, other authors, including Longwell, later proposed and acknowledged a Cenozoic age, even to the extent of bracketing movement between 10.7 and 15 m.y. ago. The bases for this age are (1) Fleck's (1967, 1970) determination that "structures in 15 m.y. old strata are rotated amounts equal to those in Paleozoic strata," and that "volcanic units dated at 10.7 m.y. are undeformed by the zone" (also, Ekren et al., 1968, reported a change in trend of faults younger than 17.8 m.y. as they near the Las Vegas shear zone), and (2) Longwell's (1974) report of large landslide masses of granitic materials incorporating the 17 ± -m.y.-old Thumb Formation near Frenchman Mountain whose source is offset 64 km eastward in the South Virgin Mountains. Many published interpretations of geologic features in the Las Vegas region are rooted in these reports.

Implicit in Fleck's (1967, 1970) and other interpretations is the assumption that structures in 15-m.y.-old strata have been rotated about a vertical axis in response to movement on the Las Vegas shear zone; the outcrop of Miocene Horse Springs Formation near Fossil Ridge northwest of Gass Peak seems to be the key exposure. Unless there is some separate supportive evidence such as paleomagnetic data from these Miocene rocks, these structures may well have formed in their present positions without significant horizontal rotation. The fact that there is parallelism between structures in valeozoic and Miocene strata could mean that older compressional structural trends controlled the orientation of younger extensional ones. This is a common feature in other parts of the thrust belt. For instance, if similar reasoning was used to analyze well-known changes in trend of structures in the Wyoming–eastern Idaho–northern Utah thrust belt, then one would conclude that these changes are post-Miocene, which we know they are not.

Longwell's (1974) analysis involves a right-lateral offset along the Las Vegas shear zone of a granitic source area (South Virgin Mountains) that was originally north of an area of deposition of granitic breccias found in the 17 ± -m.y.-old Thumb Formation at Frenchman Mountain. Subsequent left-lateral offset of the Las Vegas shear zone along what is now called the Lake Mead fault system (Bohannon, 1979) is required in Longwell's interpretation. Later mapping and interpretation by Bohannon (1979) indicates that any projection of the Las Vegas shear zone cannot extend southeast past the northeast-trending left-lateral Lake Mead fault system. If this is true, the granitic source area must have been south of Frenchman Mountain and offset by movement on the Lake Mead fault system, as shown in Wernicke et al.'s (1983) paper, not on the Las Vegas shear zone. This is contrary to Longwell's interpretation and means that the shear zone had no part in offsetting source and deposit—i.e., the age of these granitic breccias have no bearing on the age of the Las Vegas shear zone.

If the Las Vegas shear zone is not a Miocene right-lateral fault (or faults) hidden beneath Las Vegas Valley, then what is it? As Bohannon (1979) said, "One thing is certainly true—it is a zone of right oroflexural bending." I submit that this bending and possible right-slip faulting are a result of eastward transport of rocks that compose the Keystone (Red Springs)–Muddy Mountain (Glendale) thrust sheet over a northwest-striking, northeast-facing, low-angle lateral ramp in the thrust fault plane during Late Cretaceous time. Oblique movement over such a ramp would bend and displace older thrusts (e.g., Wheeler Pass) and also result in a component of extension on the thrust sheet which may explain atypical normal faults such as the La Madre fault. The ramp would bottom on a Cambrian detachment and would occupy the area generally ascribed to structural influence of the Las Vegas shear zone. This neatly solves the problem of where the shear zone begins and ends. This is similar to Longwell's perceptive original interpretation, with the concept and consequence of major lateral ramps in thrust fault planes incorporated. Perhaps we should return to the point where a late Tertiary age for the Las Vegas shear zone became generally accepted and re-evaluate.

REPLY

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We thank Royse for explicitly raising a point that we did not make completely clear in our paper: evidence that establishes a Tertiary age for the development of the Las Vegas shear zone. This is a problem not only for the shear zone but for the Garlock fault as well. In the case of both faults, the principal matching features across them which demonstrate large displacement and/or bending are of Mesozoic age or older, indicating that displacements could have occurred during the Mesozoic.

We and others before us have argued that reconstruction of the movement on these faults demands differential crustal extension (see Davis and Burchfiel, 1973, and Guth, 1981, for detailed documentation of this point for the Garlock fault and Las Vegas shear zone, respectively). This is borne out in the proverbial pudding: highly extended terranes do in fact exist precisely where the reconstructions predict [e.g., the Desert Range area (Guth, 1981) and the southern Death Valley region (Davis and Burchfiel, 1973)], thus independently confirming the intimate kinematic coordination between strike-slip faulting and extension. It is the unequivocal Tertiary age for the extension that thus establishes a Tertiary age for the strike-slip faults.

In some areas the geology suggests that Tertiary rocks and structure are involved in movements along the Las Vegas shear zone. In the northern part of the Specter Range (Burchfiel, 1965), Paleozoic rocks show the same right-lateral bending present all along the north side of the Las Vegas Valley shear. These rocks are unconformably overlapped by Tertiary sedimentary and volcanic rocks that strike northeast and contain northeast-trending folds. Their structural trends can be interpreted to have been rotated by movement on the northwestern extension of the Las Vegas Valley shear zone.

In reviewing the geology of the Nevada Test Site area, Ekren (1968) showed that two sets of high-angle faults are present: first and oldest are faults that trend northwest and northeast, and second are faults that trend north-south. The oldest set occurs in rocks older than 17 m.y., and the youngest set began to develop between 17 and 14 m.y. ago. The older fault set was not reactivated during the time the younger fault set was formed, and offsets of the older rocks by the younger fault set indicate that they are not reactivated older faults (Ekren et al., 1968). The north-south faults when followed to the south progressively trend more to the northeast, and this geometry was interpreted by Ekren as the result of drag on the Las Vegas Valley shear zone. These data we believe *are* evidence that the bending along the shear zone is Tertiary in age.

Paleomagnetic work must be done on the Tertiary rocks to unequivocally show rotation about a vertical axis. Preliminary studies on the Tertiary rocks in the Gass Peak area have been attempted. Unfortunately, the rocks did not yield good data. More work is planned in similar rocks along the shear zone.

Timing aside, Royse's suggestion that the Las Vegas shear zone represents a major transverse ramp in the Keystone thrust plate seems highly unlikely to us because of the remarkable similarity of the thrust belt north and south of it. Major ramp-tear structures of the magnitude proposed by Royse are typically engendered by pronounced paleogeographic anomalies, resulting in marked differences in the configuration of thrust plates and rock sequences contained in them on either side of the structure (for example, compare the Idaho-Wyoming sector of the thrust belt with the southwestern Montana sector). On either side of the Las Vegas shear zone, three major thrust plates plus the autochthon, each containing virtually identical paleogeographic units, correlate one-to-one.

In summary, we believe that evidence in favor of a wholly Tertiary history of movement on the strike-slip faults is quite compelling, and we see no further need to entertain hypotheses that regard their movement to have occurred either partly or entirely during the Mesozoic.

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BOOK REVIEWS

Algeny. By Jeremy Rifkin. Viking, New York, 1983, $14.75.

"Algeny" (a term that likens gene engineering to alchemy) is Jeremy Rifkin's attempt to transmute vague public fears of gene engineering (and, for that matter, of science in general) into gold. The book is proof that one can assemble a series of quotes from sources as disparate as St. Augustine and *Newsweek* and a title from one of Joshua Lederberg's neologisms and find a publisher. Any informed reader, tantalized by extravagant claims and accolades on the book's jacket will be sorely disappointed by the complete absence of novel ideas within. Rifkin has bought, completely and uncritically, the views of one school of historians who assert that the world view of an era is no more than an evanescent reflection of that era's preoccupations. Thus, the Darwinian theory of evolution through natural selection is merely a reflection of "the industrial state of mind." In the years ahead, according to Mr. Rifkin, attacks on Darwin's theory will triumph, "leaving Darwin a lifeless corpse." By this, he means not merely Social Darwinism but evolution as a world view! The core of the book is a pastiche of quotes from the pet antievolutionary authors all too familiar to those who have perused this melancholy genre. Chapters 3 and 4 betray an almost total incomprehension of what evolution is all about. We are told, in all seriousness, that the very idea of vestigial organs is macabre, that species are static entities, that spontaneous biopoesis is mathematically impossible, that Darwin's theory is scientifically bankrupt. Rifkin's few pages devoted to paleontology are a mishmash of half truths and out-of-context quotations that betray an apparent lack of knowledge of current work. This paleontologic pottage is even spiced with a straight-faced quote from biochemist Duane Gish's *Evolution: The Fossils Say No* (wherein 18th century catastrophism and special creation are presented as superior to modern geological theory). Rather than looking forward, *Algeny* looks longingly into the past. We are told that biotechnology is about to "engineer the life spans of all [!] living things." Rifkin's solution is straight out of pop books of the 60s: Either we give up bioengineering and choose to live ecologically or the cosmos wails. No doubt *Algeny* will soon be quoted in the creationist literature as an authoritative and devastating critique of evolution. Unfortunately, we cannot simply ignore such works, for they feed the growing antiscientism and irrationalism of our society.

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Petrography: An Introduction to the Study of Rocks in Thin Section (second edition). By Howel Williams, Francis J. Turner, and Charles M. Gilbert. W. H. Freeman and Company, San Francisco, 1982, 626 p., $29.95.

The first edition (1954) of *Petrography* by Williams, Turner, and Gilbert is one of the most dog-eared books in my personal library. I have used it extensively, both as a reference for thin-section studies and as a supplementary textbook for petrology classes that I taught. The treatment of textures, particularly the outstanding illustrations, has been invaluable, and the discussion of rock compositions has been satisfactory. I welcome the second edition. In order to determine the use of the first edition by others, I talked with four field geologists at the U.S. Geological Survey. All use the petrographic microscope to complement their field work and were pleased to learn that a new edition of the book is available. One even called his first edition the "rock bible." Their comments and enthusiasm reinforce my opinion that this new edition should