ic model in their paper," he says, and their decision to separate the two groups of siblings in that manner seems "arbitrary and does not correspond to any precise genetic hypothesis." Of course, he adds, "even if it were after the fact and arbitrary, there could still be something to it. But if we look at our own data in the same way, [their theory] doesn't seem to hold up. We have other data that we weren't going to publish because our initial results were so resoundingly negative, but we're putting it together now because of this article and we'll publish it. We find just a completely random distribution of data."

C. Robert Cloninger of the Washington University School of Medicine concedes that Weitkamp and Stancer have an "important hypothesis, but the experimental support for it is questionable." He is particularly concerned by the fact that their overall data for haplotype sharing agrees with a distribution that would be predicted by chance, and that the increased sharing occurs only in one small subgroup. He and his colleagues at Washington University have conducted computer simulations of several types of potential inheritance, and they find that the type of associations observed by Weitkamp and Stancer can occur only under very special conditions, depending upon the frequency of occurrence of the susceptibility genes and their degree of expression. The observed linkage thus could have occurred solely by chance. "In their defense," he adds, they also found an increased sharing among well siblings. He thinks that their report is "not a compelling argument," but concludes that "the body of data is not at a stage where we can either accept it or reject it."

Interestingly, Weitkamp's earlier paper on diabetes has not provoked nearly as much reaction, perhaps because there is already strong evidence of genetic linkage in that disease. Françoise Clerget, a French geneticist visiting at the National Institutes of Health, considers that Weitkamp's work confirms results already known, but argues that his method does not give any more information than other approaches and does not seem to provide any advantage. Other investigators seem to have reached much the same conclusion. Weitkamp concedes that his results are not critical in proving a linkage in diabetes, but argues that the results in diabetes are critical in proving the case for HLA linkage of the depression susceptibility gene. But as far as the hypothetical depression susceptibility gene is concerned, everyone agrees on only one point: the study needs to be replicated before any more firm conclusions can be drawn.

—Thomas H. Maugh II

Palmdale Bulge Doubts Now Taken Seriously

Researchers were skeptical of the claim that the bulge never existed, but new data have many wondering about its true size

The Palmdale Bulge, that ominous swelling of 83,000 square kilometers of southern California real estate, had been all too real to geophysicists. Immediately upon the bulge's discovery in 1975 (it apparently sprang into existence around 1960), they had to consider whether its appearance meant that a great earthquake was imminent. Addressing an earthquake prediction meeting in the spring of 1980, Wayne Thatcher of the U.S. Geological Survey (USGS) in Menlo Park spoke for many when he said that "honest investigators may disagree on details [of the bulge], but so many separate pieces of data support its existence that something like this must have happened." But now, Thatcher and many other researchers are much less certain of the bulge. The existence of a bulge as high and as extensive as the one claimed "is up in the air," he says. "A number of sources of error once thought to be unimportant need serious consideration."

Thatcher and others are most concerned about the effects of optical distortion on the measurement of the height of the bulge (apparently 30 to 45 centimeters). David Jackson of the University of California at Los Angeles (now temporarily at the Goddard Space Flight Center, Greenbelt, Maryland) had mentioned 2 years ago that error due to the atmospheric refraction of light could have helped make the bulge seem much larger than it was, if it ever existed at all. But the controversy had not included serious consideration of the atmospheric refraction problem until some researchers went back to the field to see just how accurate the century-old measuring technique really is.

Precise elevation determination, or geodetic leveling, is deceptively simple. Two 3-meter-long rods are erected about 60 meters apart. A surveyor stands midway between them, peering at first one and then the other rod through a small, horizontally mounted telescope. But this simple system can be used to measure some astonishingly small differences. In the case of the bulge, Robert Castle and his colleagues at the USGS in Menlo Park reported that an area of southern California 250 kilometers by 100 kilometers had risen a mere 25 to 45 *centimeters* above the surrounding land. Even the steepest part of the uplift spanned a distance of 70 kilometers (7 million centimeters) and included a 1000-meter (100,000-centimeter) climb up the Transverse Range. In order to measure such subtle changes over large expanses, the setup of two rods and a leveling instrument is moved one 60-meter step at a time from areas unlikely to move up or down quickly to the less stable, more mountainous areas.

It is this repetition and the consequent accumulation of error that concerns researchers. During the first setup, the surveyor looks back along a horizontal line toward the precisely ruled scale on the first rod, which is standing on a permanent elevation marker, and ahead at the scale of the second rod. The difference between the heights sighted on the two rods is the difference in elevation between their two locations. The first rod is then moved ahead of the second, and the surveyor makes the same kind of sightings from between the two rods. This gives the second increment of elevation difference along the leveling line. A surveying team will repeat this process as many as 1000 times to determine the difference in elevation over a leveling route 50 kilometers long.

Engineers have used these leveling lines to create a network of precisely determined elevation markers that are reference points in the construction of railroads, pipelines, and highways. Castle and his group looked instead at differences in elevation that showed up between relevelings at the same site. Be-

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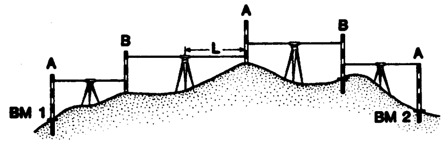
cause the increases that they found apparently exceeded any known errors, they concluded that the land had risen between 1959 and 1974. Since 1974, the uplift seems to have partially collapsed.

A number of researchers are now concerned that the errors in leveling are actually larger than anyone suspected when Castle and his group announced the discovery of the uplift in 1975. One possibly large error, some fear, is the misreading of the rods resulting from the bending of light passing through the warm air near the ground.

Because the commonly cited experiments supporting the insignificance of this refraction error were conducted in the cool climes of Finland, Charles Whalen of the National Geodetic Survey (NGS) in Rockville, Maryland, ran experiments in July 1979 at a site in Gaithersburg, Maryland, and at another site in Tucson, Arizona, to measure the magnitude of the refraction error under conditions more typical of the United States. William Strange of NGS analyzed the results and found that refraction altered the apparent elevation of a rod sighted from 60 meters away by a fraction of a millimeter. If that error accumulated over a leveling line that gained almost 500 meters in elevation, the total error would be 8 centimeters under the conditions of the Maryland experiment and 14 centimeters under those in Tucson.



Leveling procedure

Surveyors determine the elevation difference between benchmark (BM) 1 and BM 2 by first sighting rod A (on BM 1) and then rod B through a horizontal telescope. Rod A is then advanced to its next position along the leveling line and the process repeated until BM 2 is reached. L is the sight length. [R. S. Stein, in Earthquake Prediction, *copyright 1981 by the American Geophysical Union]*

Strange then calculated the likely effect of a refraction error of that magnitude on past levelings in southern California. No one had yet demonstrated that refraction errors would indeed accumulate over the hundreds of leveling setups and weeks and months of time required to complete a single leveling line. And he did not know how the sun's heating of the ground had warmed the air at each of the thousands of leveling setups involved. It is the strength of the temperature gradient in the first few meters above the ground that determines the size of the refraction error. This nonlinear gradient bends a sighting taken down a slope less than a sighting taken up the slope. Strange had to estimate these gradients.

Strange did know that around 1960, when much of the uplift supposedly occurred, surveyors were shortening the average length of a sighting on some leveling lines from about 60 meters to about 30 meters. They had not been correcting for refraction but wanted to minimize the error, which is proportional to the square of the sight length. Before the shortening, the refraction error, if it were as large as the NGS experiments suggested, would have made the Transverse Mountains appear less tall than they were. After the shortening, they would have appeared to pop up.

Strange concluded that the refraction error and the well-intentioned attempt to minimize it caused most of the apparent uplift. After making an approximate correction for refraction, only 5 to 10 centimeters of uplift, not 30 to 45, remained. That uplift, he says, was localized along the San Andreas and San Gabriel faults. The uplift that did occur may have simply been the earth's response to the accumulating crustal stress that eventually produced the San Fernando earthquake of 1971, he says.

Most researchers thought that Strange was on the right track, but they were not convinced that an effect found at one site in Tucson would persist over tens of kilometers of California countryside. So Thatcher, Ross Stein of the USGS, Strange, Whalen, and Sandford Holdahl of NGS ran a field experiment along a 50-kilometer leveling line from Saugus to Palmdale. This is one of the half-dozen or so lines whose interpretation is critical to the existence of the uplift. While measuring the temperature gradient in the first 2.5 meters above the ground, they ran two leveling lines, one with an average sight length of about 42 meters and another of about 24 meters.

Both Strange's approximate refraction correction and a standard calculation, which included the observed temperature gradient, predicted that the elevation differences measured by the short- and long-sight-length levelings would differ by about 4 centimeters. The long-sight-length survey did indeed show Palmdale to be 4.02 centimeters lower than the one having short sight lengths. "I was surprised," Thatcher says, "that the refraction error was as consistent as this, that it persisted along so much of the line."

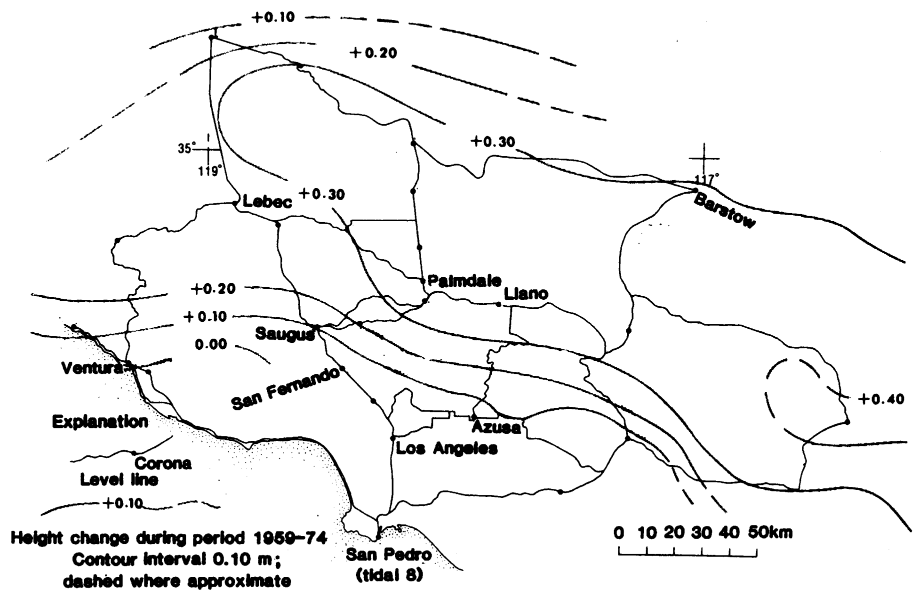
The researchers who took part in the California field experiment believe that they have demonstrated the significance

NASA/USGS

The Palmdale Bulge from space

This satellite view shows the San Andreas fault running across the photograph, intersecting the Garlock fault at left center. The reported bulge, a broad uplift of only 30 to 45 centimeters, is not evident, but it covers most of the upper two-thirds of the area shown, beginning at the edge of the mountainous region just north of Los Angeles (lower right).

of the refraction error, but they are not certain whether it will shrink the uplift to a less ominous size or will leave it only slightly changed. "Most people would say that [the Saugus-Palmdale line] was the optimal one to look at for an effect," Thatcher says. "Whether it applies to the rest of southern California is not clear." The group's main concern is that most of that line runs along the tracks of a railroad right-of-way, which provided a uniform and efficient surface for the generation of a temperature gradient. Over the few leveling sections sighted over soil, concrete, asphalt, or sparse vegetation, the ability to predict the error from the temperature gradient was not as good. In their preliminary analysis,* the group concludes only that refraction errors can accumulate until they are significant. Stein does add that "it will definitely make it [the uplift] smaller."



The Palmdale Bulge

As now proposed by Robert Castle and his group. [Adapted from R. K. Mark et al., *in* Journal of Geophysical Research, *vol. 86, p. 2783 (1981)]*

"I don't think the results are definitive," Castle says. He points out that the conditions of the field experiment, including the relatively light winds encountered, were nearly ideal for detecting the effect. In addition, he suspects that 26 of the 40 millimeters of observed elevation difference result from an unknown error unrelated to refraction. This error seems, he says, to depend on the direction, toward Saugus or Palmdale, of a sighting. Almost three-quarters of the sightings that account for most of the 40 millimeters are in the same direction, he notes. Stein responds that the lopsided distribution might easily be a matter of chance because only 17 of the sightings accounted for most of the difference. To be certain, they are checking the possibility that the orientation of the line with respect to the sun could be significant.

The type of leveling error originally emphasized by Jackson, miscalibration of the leveling rod scales, now appears to be more significant than once thought, but so far it does not appear to be crucial to the existence of the uplift. Jackson had identified a specific case, the 1964 leveling of the line between San Pedro and Palmdale, in which a rod calibration error had apparently contributed to the supposed uplift. In that instance, Jackson found a relatively large error of 100 parts per million. That could add up to 10 centimeters over a typical leveling line across the Transverse Range.

At the time, Jackson called this error typical, but he now sees it as an extreme case, an error of 50 to 70 parts per million being more typical. That is still higher than other estimates, according to Stein. Stein analyzed leveling lines that were not likely to be affected by refraction, and Strange inspected records of repeated calibrations of the same rods. Both found that most errors have been about 30 parts per million, or about 3 centimeters over terrain having 1 kilometer of relief.

Most researchers agree, however, that a few large rod calibration errors have occurred. Jackson's discovery of a bad rod used in the 1964 San Pedro–Palmdale leveling is widely accepted. Robert Reilinger and Larry Brown of Cornell University believe that they have also found enough rod error in the 1962 leveling between Azusa and Llano, another important line, to completely account for the reported 7-centimeter uplift. Although other large rod errors have not been found, Jackson notes, researchers have not been able to examine many lines closely. The data are in an awkward form for tracing individual rods from line to line, he says, and it has been difficult to separate rod-related error from refraction error.

The status of one other possible problem remains particularly muddled. If some of the sediment-filled basins along the foot of the Transverse Range sank, that could account for the observed relative movement and eliminate the need for the postulation of an uplift in those areas. Such basins can sink rapidly if the pumping of water from their aquifers is fast enough. Reilinger contends that the behavior of leveling lines across the Saugus Basin indicates subsidence before 1964 under the influence of dry weather and high pumping rates. Subsidence can conceivably account for all of the 9 centimeters of apparent uplift claimed for the region adjacent to the basin, he says. Stein disagrees. He argues that most of the water was pumped from a thin, gravelly aquifer that could not have compressed enough to account for more than a tenth of Reilinger's subsidence. Resolution of this question does not appear to be imminent.

A consensus of sorts does seem to have developed on two points since Jackson first raised doubts about the uplift 2 years ago. First, most researchers directly involved in analyzing the data believe that the evidence requires careful reevaluation. The errors appear larger now than they did a few years ago. Whether the differences between repeated levelings exceed the error enough to warrant the conclusion that there was a broad, relatively high uplift is uncertain, they say.

Second, most researchers deny that rapid uplift in southern California was only an illusion. As Reilinger says, "Some of the data look very good. It's quite likely that tectonic deformation is occurring." Even after making his corrections for refraction and rod errors, Strange finds 5 to 10 centimeters of uplift along the San Andreas and San Gabriel faults. Stein still finds an uplift of 10 to 15 centimeters between 1955 and 1971 near Lebec on the San Andreas fault at the northwest end of the reported uplift. The question now is not whether an uplift occurred, but whether it was a mind-boggling behemoth or a more subtle, more easily understood reaction to the shifting stress in the earth's crust.

—Richard A. Kerr

*An abstract submitted to the International Association of Geodesy Symposium, Tokyo, 7 May 1982.