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EARTHQUAKE HAZARDS OF THE SAN GABRIEL VALLEY, SOUTHERN CALIFORNIA

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ABSTRACT:

The densely-populated San Gabriel basin has not previously been characterized as to its earthquake potential. The basin is bounded by the Sierra Madre-Duarte reverse faults and the Raymond left-slip fault on the north, the East Montebello right-slip fault on the west, and east-trending folds of the Puente Hills and San Jose Hills on the south and east. Five moderate

earthquakes struck the margins of the basin in 1988-1991 (Whittier Narrows, 1987; Pasadena, 1988; Upland, 1988, 1990; Sierra Madre, 1991), allowing seismicity insights that supplement gravity and magnetic data and seismic tomography. The LARSE-1 deep crustal profile crossed the center of the basin. In addition, more than 60 wells drilled by the oil industry and several ground-water geological studies allow insights into the subsurface. New 1:24,000-scale geologic maps published by S. Tan of the California Geological Survey and T.W. Dibblee aided the interpretation.

The San Jose fault, previously considered as a left-lateral fault that was the source of the 1988 and 1990 Upland earthquakes, is a north-dipping reverse fault that is part of an east-trending fold-thrust belt, including a partly blind reverse fault source beneath the San Jose Hills and a blind reverse fault beneath the Walnut anticline to the south. The Walnut Creek fault, bounding the San Jose and northern Puente Hills on the west, may be a left-slip fault that is the southwestern continuation of the fault generating the Upland earthquakes. This fault separates strongly-folded strata of the San Jose and Puente Hills from nearly flat-lying strata of the San Gabriel Valley. The San Gabriel Valley, in contrast to regions surrounding it, is only gently deformed and may not be underlain by a separate earthquake source other than a horizontal decollement fault proposed as a result of the LARSE-1 line. The East Montebello fault is the northwestern continuation of the Whittier fault with a low slip rate because much of the Whittier fault slip rate has been taken up by folding on the Montebello anticline. The East Montebello fault is traced in the subsurface as far north as the northern edge of the Repetto-Monterey Park Hills but no farther, suggesting that this right-slip fault is only now propagating across the basin toward the San Gabriel Mountains. Within the Puente Hills, north-south faults with normal separation may be active, especially the Handorf fault; uplift of the hangingwall side of this fault brings older alluvium against younger alluvium; San Jose Creek is antecedent to this uplift.

Investigations Undertaken

This project focused on the earthquake hazards of the densely-populated San Gabriel Valley, a tectonic basin immediately east of the Los Angeles Basin that has not previously been characterized as to its earthquake potential. The Valley is a triangular-shaped structural basin bounded on the north by the east-trending Sierra Madre-Duarte reverse fault set and the Raymond left-lateral fault, on the southwest by the Elysian Hills and the East Montebello right-slip fault, and on the southeast by the San Jose Hills and Puente Hills. The LARSE-1 deep seismic crustal profile crossed the basin from southwest to northeast. In support of this profile, gravity and magnetic data were used to assist in structural interpretation. The margins of the basin have been the sites of five earthquakes in the period 1987-1991: the 1987 Whittier Narrows reverse-fault earthquake on the south, the 1988 Pasadena strike-slip earthquake on the northwest along the Raymond fault, the 1991 Sierra Madre reverse-fault earthquake on the Sawpit-Clamshell cross fault north of the Sierra Madre fault, and the 1988 and 1990 Upland earthquakes on a buried left-slip fault northeast of the San jose Hills.

The valley has been penetrated by oil-exploratory and development wells and water wells

that comprised the primary data set used in this study. This has been superimposed on recently-acquired geologic mapping at 1:24,000 scale by the Dibblee foundation and the California Geological Survey. These maps update older maps at the same scale by A.O. Woodford and John Shelton in the north and by R.F. Yerkes and D.L. Durham of the USGS in the south. I have constructed structural cross sections that extend across the San Gabriel Valley in the San Jose Hills and Puente Hills to determine the structural relation between the two regions.

With the help of Eric Fielding of JPL, I recently acquired a re-processed USGS 10-m digital elevation model (DEM), which I have analyzed using RiverTools. This model allows visualization of subtle geomorphic features that are strongly influenced by active structures, especially blind thrusts. In addition to the San Gabriel Valley, northern Puente Hills, and San Jose Hills, I have applied this DEM to the rest of the Puente Hills and the Coyote Hills, subjects of previous NEHRP awards.

Thomas K. Bjorklund has completed a PhD dissertation at the University of Houston, partly under my direction. This dissertation comprised a detailed subsurface analysis of the Whittier fault, including isopach maps, structure contour maps, and 30 subsurface cross sections through oil fields along the Whittier fault, with some sections extending both south and north of the fault. His northern sections tie into my own secgtions in the northern Puente Hills, San Jose Hills, San Gabriel Valley, and Coyote Hills, allowing a three-dimensional analysis of the Puente Hills and surrounding regions. Bjorklund's sections and maps will be available on a CD-ROM sometime in 2002.

Results

San Jose fault. The 1988 and 1990 Upland earthquakes occurred on one or more left-lateral strike-slip faults striking NE, a strike similar to that of the San Jose fault. Based on these earthquakes, it was assumed that the San Jose fault is a left-lateral strike-slip fault, and it appears this way in the standard southern California fault model. Detailed surface and subsurface work showed otherwise. The San Jose fault is a reverse fault on the south side of the San Jose anticline, an anticline that verges southward. Geotechnical exposing the fault at California Polytechnical Institute at Pomona is consistent with this interpretation. The anticline steps left to a western segment, and the fault steps left, too, and dies out downplunge on the south limb of the anticline. This is a return to the original interpretation of John Shelton and A.O. Woodford nearly a half-century ago based on their own surface and subsurface mapping.

Uplift on the anticline has produced the San Jose Hills, although the west plunge of this anticline may be much older. Cretaceous granitic rocks at the eastern end are overlain westward by Miocene Glendora Volcanics, Topanga Formation, and Puente Formation. The anticline and fault are bounded on the south by the Amar syncline, which follows a topographic low, occupied in its eastern part by San Jose Creek. South of this is the west-plunging Puente Hill anticline,, housing the Walnut oil field. I have renamed this fold the Walnut anticline to prevent confusion with the larger-scale Puente Hills anticlinorium flanking the Whittier fault on the north. The

Walnut anticline is succeeded on the south by another syncline, named here the Industry syncline because it passes through the City of Industry and is followed by Valley Boulevard, a major arterial highway following the structural low.

Accordingly, the northern hills are uplifted along a previously-unknown fold-thrust belt, largely verging southward. The San Jose fault is a reverse-fault earthquake source, and a blind fault underlying the Walnut anticline appears to be another earthquake source. Both dip north, and they might converge at seismogenic depths as a single earthquake source.

Walnut Creek fault. Where is the southwestward continuation of the fault that was the source of the Upland earthquakes, if not the San Jose fault? The California Division of Water Resources proposed that the irregular range front of the San Jose Hills and northern Puente Hills is marked by a NE-striking fault that separates the folded Puente Hills and San Jose Hills from the nearly flat-lying deposits of the San Gabriel Valley. This fault has been named the Walnut Creek fault. West of the San Jose Hills, the Walnut Creek fault separates La Vida and Soquel members of the Puente formation on the south from Topanga Formation on the north in the Texaco Covina 5-1 well. The high-resolution DEM shows some evidence of NE-striking lineations marking breaks in the topography at about the position expected for the Walnut Creek fault. In the City of San Dimas, Walnut Creek flows SW to the range front of the San Jose Hills, then flows parallel to the range front in a steep gorge, eroding to bedrock, then flows westward across the San Gabriel Valley.

The most compelling evidence is the structural contrast between folded strata of the San Jose Hills and Puente Hills and nearly flat-lying strata of the San Gabriel Basin. This requires considerable shortening of the Puente Hills and San Jose Hills relative to the San Gabriel Valley. The San Gabriel Valley, underlain by crystalline basement rocks, may drive southward as a rigid block against the margin of the Los Angeles basin, accumulating slip on the Walnut Creek fault from north to south. This may account for the fact that the Walnut Creek fault does not continue as far southwest as the westernmost Puente Hills. The relation between this southward-driving San Gabriel Valley block and a decollement beneath the San Gabriel Valley based on interpretation of the LARSE-1 line is still under investigation.

San Gabriel Valley block. In contrast to regions to the southwest, south, east, and north, the San Gabriel Valley block is only gently deformed, and it may not be underlain by a separate earthquake source other than those sources around its edges. The valley is underlain by a sequence up to 2 km thick of non-marine Plio-Pleistocene gravels, sands, and claystones underlain by a transgressive sequence of shallow-marine sands and clays, commonly referred to as “Fernando”, “Pico”, or “Repetto.” Throughout most of the valley, these deposits rest with angular unconformity upon Miocene (Mohnian and Luisian) lower Puente Formation, Topanga Formation, and Glendora Volcanics, which rest on Mountain Meadows Dacite and pre-Tertiary crystalline basement. These coarse-grained deposits are exposed only close to the San Gabriel mountain front, where they are called the Duarte Conglomerate. The marine deposits contain

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fauna indicative only of facies and water depth, and so an age in millions of years or a correlation to the Los Angeles Basin stratigraphy has not been successful.
Toward the southwest, the non-marine sequence is underlain by strata that are more successfully correlated to the Pico and Repetto members of the Fernando Formation, and at Whittier Narrows, a full sequence of this age is preserved on both sides of the East Montebello fault. The base of the non-marine sequence rises toward the East Montebello fault, either as a facies change to deeper marine strata on the southwest or as an angular unconformity. Unconformity or facies change? The answer to this question is not yet at hand, in part because the contact between non-marine deposits and Fernando Formation is not exposed north of the Elysian Hills or Puente Hills.

North-south faults in the western Puente Hills. The Walnut anticline at Walnut oil field is cut by a north-south fault that forms the up-dip trap for oil there. This west-side-up fault forms a small east-facing range front that suggests that it may be active. Farther southwest, the Handorf fault marks an east-facing range front in the Turnbull oil field near the City of Hacienda Heights. The range front is especially prominent in the 10-m DEM, not only where bedrock is exposed on the west, but also north of San Jose Creek, where there is a prominent lineation and east-facing scarp between dissected older alluvium and non-dissected younger alluvium. This fault dips east in the subsurface and has normal separation. San Jose Creek is antecedent to uplift of the western block of the Handorf fault. A third east-facing range front west of the City of Rowland Heights, followed by Fullerton Road and the northern extension of Powder Canyon, is another possible fault, although separation has not been demonstrated in the surface or subsurface.

These faults are not the same as the Workman Hill fault and North Whittier Heights fault that extend NNW from the Whittier fault. These faults, also with normal separation, cut the Miocene Sycamore Canyon Member of the Puente Formation and the Repetto Member of the Fernando Formation, but do not cut the Pico Member in the westernmost Puente Hills. Although surface maps extend these faults in the subsurface of the San Gabriel Valley, there is no well data to support this continuation, nor is there evidence for such a continuation in the gravity data.

My best explanation at present is that the north-south faults with geomorphic expression represent east-west extension of the Puente Hills accompanying north-south contraction across the fold-thrust belt. They are relatively short, and their displacement is small, suggesting htat they are not independent earthquake sources.

Summary statement. The use of subsurface petroleum-industry data, water well data, and detailed DEM analysis has permitted for the first time the delineation of earthquake fault sources in the northern Puente Hills and adjacent San Gabrield= Valley, thereby improving the fault model for the eastern Los Angeles metropolitan area.

Non-Technical Summary

The earthquake potential of the eastern Los Angeles metropolitan area has been poorly

understood, despite the large population at risk there. Using subsurface data from the petroleum industry, water wells, new surface geologic mapping, and detailed computer-generated topography of the Puente Hills and San Jose Hills, we have identified two new earthquake source faults beneath the San Jose Hills and northern Puente Hills. The boundary between the hills and the San Gabriel Valley may be another earthquake source fault, related to the fault that generated the Upland earthquakes of 1988 and 1990. The San Gabriel Valley itself is apparently not underlain by an earthquake source fault except around its margins.

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