Time-dependent land uplift and subsidence in the Santa Clara valley, California, from a large interferometric synthetic aperture radar data set

David A. Schmidt[1] and Roland Bürgmann

Department of Earth and Planetary Science, University of California, Berkeley, California, USA

Received 28 October 2002; revised 20 March 2003; accepted 12 May 2003; published 5 September 2003.

[1] We invert 115 differential interferograms derived from 47 synthetic aperture radar (SAR) scenes for a time-dependent deformation signal in the Santa Clara valley, California. The time-dependent deformation is calculated by performing a linear inversion that solves for the incremental range change between SAR scene acquisitions. A nonlinear range change signal is extracted from the ERS InSAR data without imposing a model of the expected deformation. In the Santa Clara valley, cumulative land uplift is observed during the period from 1992 to 2000 with a maximum uplift of 41 ± 18 mm centered north of Sunnyvale. Uplift is also observed east of San Jose. Seasonal uplift and subsidence dominate west of the Silver Creek fault near San Jose with a maximum peak-to-trough amplitude of ~35 mm. The pattern of seasonal versus long-term uplift provides constraints on the spatial and temporal characteristics of water-bearing units within the aquifer. The Silver Creek fault partitions the uplift behavior of the basin, suggesting that it acts as a hydrologic barrier to groundwater flow. While no tectonic creep is observed along the fault, the development of a low-permeability barrier that bisects the alluvium suggests that the fault has been active since the deposition of Quaternary units. *INDEX TERMS:* 6924 Radio Science: Interferometry; 1829 Hydrology: Groundwater hydrology; 1884 Hydrology: Water supply; 5114 Physical Properties of Rocks: Permeability and porosity; 1243 Geodesy and Gravity: Space geodetic surveys; *KEYWORDS:* Santa Clara Valley, InSAR, time series, land subsidence

Citation: Schmidt, D. A., and R. Bürgmann, Time-dependent land uplift and subsidence in the Santa Clara valley, California, from a large interferometric synthetic aperture radar data set, *J. Geophys. Res.*, *108*(B9), 2416, doi:10.1029/2002JB002267, 2003.

1. Introduction

[2] The Santa Clara valley aquifer, located in the San Francisco Bay Area, represents a complex network of permeable, water-bearing units where groundwater is exchanged between units under different confining pressure (Figure 1). Fine-grained sediments deposited during periods of high sea level are interfingered with coarse-grained sediments derived from the surrounding uplands [*Clark*, 1924; *Iwamura*, 1995]. The layers of fine-grained interbeds consisting of mostly clay and silt restrict the vertical flow of groundwater. While groundwater flows more freely through the horizontal layers of sand and gravel, changes in stream channels during deposition disrupt the connectivity of the permeable units. The withdrawal or recharge of groundwater places the aquifer in a state of disequilibrium where hydraulic gradients drive flow. The time required to achieve equilibrium following a perturbation depends on the thickness, connectivity, and hydraulic diffusivity of permeable units [*Alley et al.*, 2002].

[3] The redistribution of groundwater produces a poroelastic response which can be observed as a surface deformation signal [*Rice and Cleary*, 1976]. Pore pressure changes, which are reflected by a change in head level, correspond to a change in the effective stress of the opposite sign. Therefore an increase in pore fluid pressure results in a decrease of the effective stress on the granular skeleton which supports the vertical load. As head levels increase or decrease, an elastic response is observed as either rebound or subsidence, respectively, of the surface typically on the order of cm.

[4] Inelastic deformation can also be observed in regions where excess groundwater pumping results in the compaction of previously saturated sediments. The pumping of groundwater from the aquifer reduces the pore pressure in the water-bearing units and the imposed hydraulic gradient drives groundwater out of the interbeds. The increase in the vertical effective stress within the interbed results in the irreversible compaction of compressible clay and silt units through the settling of grains [*Poland and Davis*, 1969]. The compaction can be observed as land subsidence with deformation on the order of meters for major aquifers.

[1]Now at Department of Geological Sciences, University of Oregon, Eugene, Oregon, USA.

0148-0227/03/2002JB002267$09.00