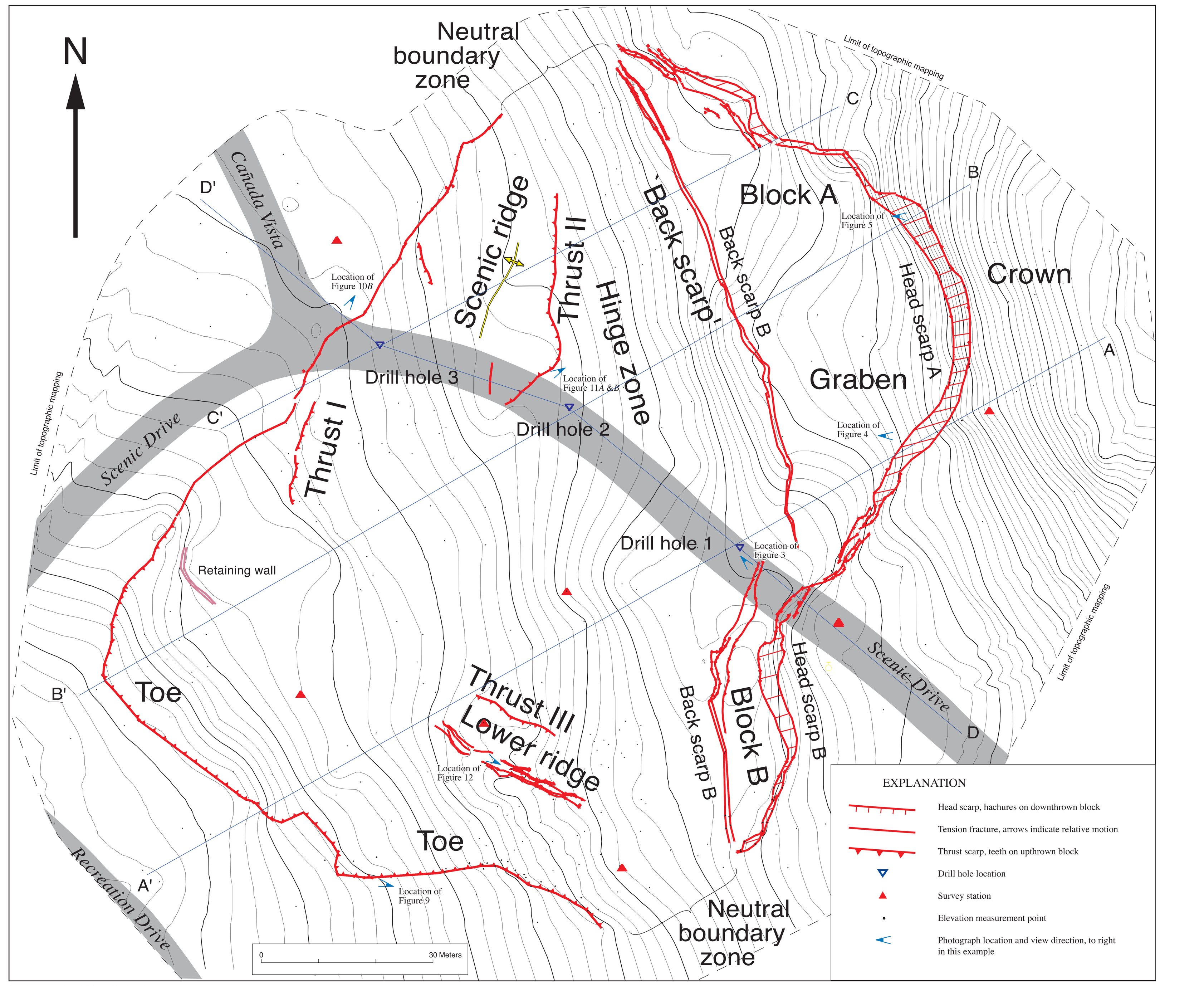
Photographic base from 6 March 1998 aerial photography

Map 1. Plot of Scenic Drive landslide boundaries and internal features. Photographic base not rectified. Features shown mapped on 21 March 1998.



Base from survey data 26 Feb. to 8 March 1998
Road locations generalized from 24,000 digital line graphics (DLG)
UTM Projection

Map 2. Topographic map of Scenic Drive landslide boundaries and internal features. Contour interval = 50 cm. Features shown in red mapped 26 February to 8 March, 1998.

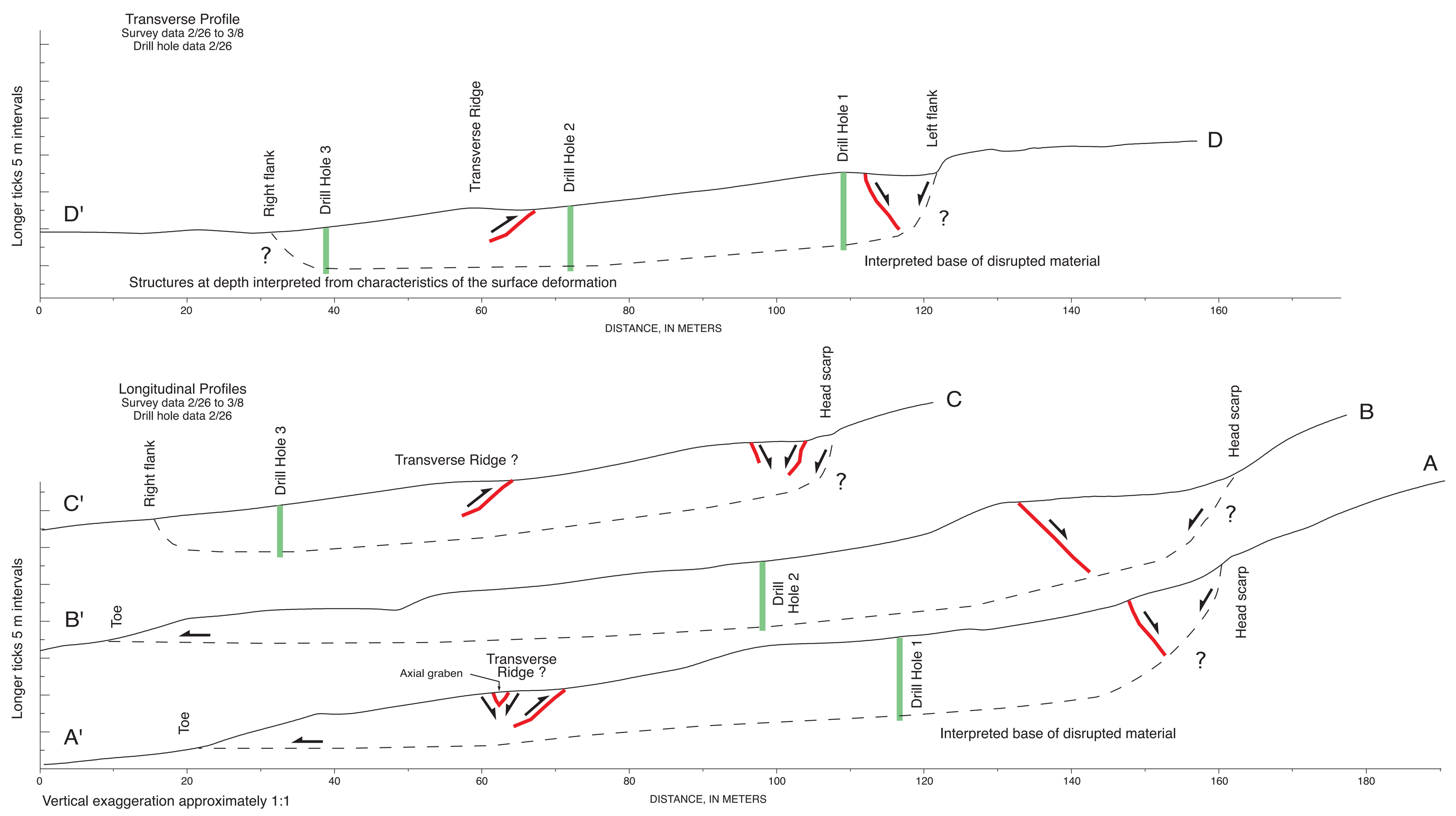


Figure 5. Cross sections of Scenic Drive landslide. Upper profile shows transverse section across the median part of the slide. The lower profiles are constructed approximately parallel to the slope aspect (and the displacement direction). Ground surface constrained by survey data, subsurface constrained by drill holes 1, 2, and 3 (DeMouthe, written commun., 1998).

INTRODUCTION

The small rural town of La Honda, Calif., is an unincorporated region of San Mateo County situated in the Santa Cruz Mountains in the western part of the San Francisco peninsula (Fig. 1). Much of the town is underlain by a previously recognized ancient landslide complex (Nilsen et al, 1979). The ancient slide complex covers about 1.0 to 1.25 sq. km, parts of which have been historically active. This report describes a recent landslide involving part of Scenic Drive, La Honda, that became active in January, 1998. This report does not describe other currently active landslides in La Honda, such as the January 1998 slide on lower Recreation Drive, or the history of sliding in the area. This report concerns the principal morphological features we observed and mapped between 11 February and 21 March 1998 (Map 1) on an enlargement of a 1:7500-scale air photo acquired 6 March 1998 and prior to that on a town property-line map, and by laser survey carried out between 26 February and 8 March (Map 2). The principal objective of this report is to make available the detailed photographic and topographic base maps and associated description of surface morphological features. For reference, Figure 2 shows the general shape of a deep-seated landslide and some of the nomenclature used in this report.

DESCRIPTION OF SLIDE ACTIVITY

Local residents with homes on the landslide reported minor structural deformation in late January. Deformation was severe enough to force residents to begin vacating their homes by 4 to 10 February. Initial activity was most pronounced near the head scarp (Figs. 3, 4). After about two weeks of heavy rainfall in early February 1998, deformation accelerated from a few mm/day to about 20 cm/day between 20 to 26 February. After 26 February rainfall decreased, mitigation efforts by the County of San Mateo were initiated (Fig. 3*D*), and landslide motion decreased. Noticeable movement again occurred following rainfall on 12 March and during the week of 23 to 26 March. As of 8 April, the slide continued to move a few mm/day.

Mitigation efforts by the county included lining with plastic the drainage ditch along Scenic Drive between the head scarp and the Scenic-Cañada Vista intersection, digging and lining with plastic a trench upslope from the head scarp, covering parts of the head scarp with plastic, and drilling three dewatering holes which penetrated bedrock along Scenic Drive (Maps 1, 2). The county mitigation efforts were carried out between 26 and 28 February.

The slide is rectangular in shape with dimensions of about 145 m by 110 m. The length from crown to toe is 162 m (Map 2). The base of disrupted material lies at a depth of about 6 to 8.5 m, as determined from drill-hole data obtained by the County of San Mateo (J. DeMouthe, Co. of San Mateo, written commun., 1998) (Fig. 5). The crown of the slide lies at an elevation of about 189 m (620 ft) and the toe at about 168 m (550 ft).

Neutral boundary zones along the edge of the slide are about 25 m wide and are present at opposite corners. These are tentatively inferred to define a ‘hinge’ 140 m long (Map 2). Upslope from the hinge the structures within the slide are all extensional, downslope from it they are dominantly compressional with subordinant or secondary extensional features. The neutral boundary zones were initially devoid of structures (11 February to 8 March), and later (after 26 March) exhibit only very small (about 1 to 10 cm) surface displacements. Offsets of the headscarp taper to zero down-slope towards the neutral boundary zones and to zero along the toe up-slope to the neutral boundary zones.

The principal displacement direction is southwest with an azimuth of about 250°, down the overall slope of the hill (Fig. 6). Slip vectors along the headscarp were measured from slickenlines exposed on the scarp surface (Fig. 7) and offset cultural features or landscape features. Slip vectors along the toe were measured from offset cultural features. The head scarp dips predominantly between 65° and 75° and slickenlines plunge directly down-dip (Fig. 7).

Part of the crown of the active slide is coincident with an older head scarp (Fig. 8) with 10's of meters of relief. The active head scarp is irregular, probably compound, with two crescent-shaped parts. The larger, head scarp A, is about 100 m long and is developed within a predominantly concave upward pre-existing morphology. The smaller, head scarp B, is about 40 m long and is developed within a convex upward pre-existing morphology. The maximum vertical displacement of head scarp A is about 4 m and of head scarp B is about 1.5 m. Volcanic rock is exposed in head scarp A and colluvial materials, probably representing older slide deposits, are exposed in head scarp B.

Distinct graben lie at the base of head scarps A and B. The graben are bounded by through-going vertical to up-slope-dipping back scarps (normal faults) that are also compound. The graben associated with head scarp A is 35 m wide and bound by a 340°-trending back scarp (up-slope dipping). Assuming that the floor to the garage of house 1 was horizontal before the slide then this block (A) is rotated about 7° into the head scarp (see Map 1). The graben (down-dropped block) associated with head scarp B is 10 m wide and bound by a 355°-trending back scarp (up-slope dipping). This block (B) is tilted about 17° toward the head scarp (again, assuming a pre-slide horizontal basement surface for house 2). Displacement on the back scarp is about 2 m at its maximum height.

The toe of the slide has about 1.5 m of relief and at least 1 m of horizontal displacement (Fig. 9). Pop-up or 'flower' structures characteristic of transpressive deformation (partly strike-slip and partly compressional) are expressed along the right flank, from the intersection of Cañada Vista-Scenic Drive (Fig. 10) and up-slope to the neutral boundary zone. The pop-up structures are 1-2 m long, 50-100 cm wide, with 10 to 40 cm relief, and are locally en echelon, separated by small-scale normal faults (Map 1). The southeast flank of the toe is upthrown with decreasing relief towards the 'hinge' zone.

Major internal structures occur within the slide. A thrust fault (Internal thrust I) and two prominent transverse ridges, here referred to as Scenic ridge (Fig. 11) and Lower ridge, lie subparallel to the northwest and southeast flanks of the toe, respectively. Internal thrust I, located down-slope from the intersection of Cañada Vista and Scenic Drive, has vertical relief of at least 0.5 m. The Scenic ridge trends approximately 200° and developed about 1 to 1.5 meters of relief between 11 February and 21 March. The up-hill side of the ridge is bound by a down-slope dipping thrust fault (Internal thrust II). Tension cracks oriented 180° continue to develop over the top of the ridge. The Lower ridge trends about 285° and has a strongly developed axial graben (Fig. 12) over its crest. The up-hill flank of the ridge is also bound by a down-slope dipping thrust fault (Internal thrust III).

Numerous other small-scale, mainly tensional fractures are present within the slide mass. The larger of these are portrayed on Map 1. Deformation also occurred down-slope from the toe, as expressed by leaning retaining walls, distorted fences, over-steepened slopes, and encroachment of a steepened slope on a tree trunk suggesting enlargement of the slide in the downslope direction. Cracking of the ground surface is widespread above the head scarp, but major new scarps have not developed as of 21 March 1998.

Deposits exposed in part of the head scarp and examined during drilling by the county for dewatering holes suggest the mass that is moving contains an older breccia deposit. The brecciated unit is underlain by friable, poorly consolidated late Miocene to Pliocene marine siltstone mapped as Purisima Formation (Cummings et al., 1962).

RAINFALL AND LANDSLIDE ACTIVITY

Seasonal relations between rainfall and landslide activity can be characterized as follows: On the central California coast, the Water Year (considered as beginning 1 July by the National Weather Service), has three important parts: (a) Wetting (autumn)--shallow soil layers are dry and rainfall that occurs is absorbed, with little or no runoff or recharge to deeper layers; landslide activity is very unlikely unless an earthquake occurs. (b) Excess Moisture (mid-winter)--moisture levels in shallow soils reach the maximum levels that the soils can retain against drainage. Further rainfall is re-routed to sub-surface recharge. Intense rainfall may also produce surface runoff as overland flow. This is the period when most landslides form. (c) Drying (spring and summer)--the reduced rainfall no longer keeps pace with the increasing evapotranspiration and the soil moisture again drops below saturation; late-season rainfalls are absorbed into the soil; new landslides are unlikely, but landslides activated during the winter may continue to move into late spring.

Figure 13 shows the seasonal accumulation of rainfall recorded by a local rain gauge and telemetered into the National Weather Service Forecast Office in Monterey, CA. The rainfall accumulation expected in a so-called normal year, based on the long-term (~40 years) NOAA rainfall records for the area, is also shown for comparision. Rainfall was well above normal from the end of November 1997 through March 1998. Using an evapotranspiration model adapted from Thornthwaite and Mather (1955), we estimate that the soils in the La Honda area should have been wetted to the excess moisture state by early December, and remained there through the end of March.

During the period 31 January through 8 February 1998, a closely-spaced series of intense rain storms deluged the area with a total of 200 mm (7.9 in) of rainfall. Because the shallow soils had already reached their moisture retention capacity, much of this rain water could percolate to potential sliding surfaces at deeper levels. The first definite movement of the La Honda landslide did occur during this rainfall period; although some residents report that they began seeing unusual features that may be related to downslope movement beginning in mid-January. This time frame is depicted in Figure 13, with a query to denote the uncertainty of the beginning of movement.

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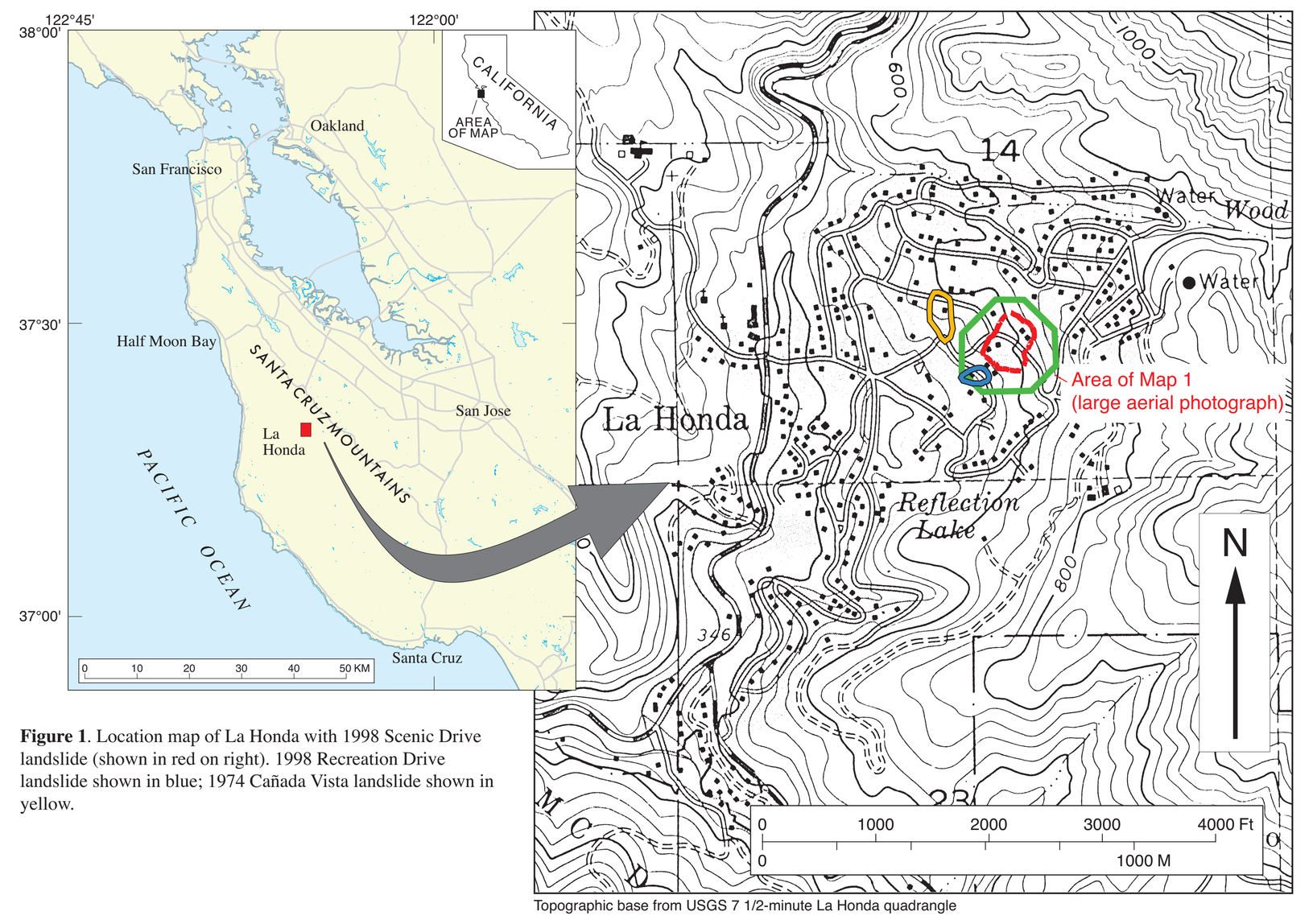
Nilsen, T.H. et al., 1979, Relative Slope Stability and Land-use planning in the San Francisco Bay Region, California: U.S. Geological Survey Professional Paper 944, 96 pp.

Thornthwaite, C. W., and Mather, J. R., 1955, The water balance: Drexel Institute of Technology, Publications in Climatology, v. 8, no. 1, 104 pp.

Figure 3. Development of landslide scarp along Scenic Drive, where 1998 slide mass offset road both vertically and horizontally, views to southeast. *A*, Minor surface cracks present during early stage of landslide development, 11 February 1998; *B*, 20 February 1998; *C*, 22 February 1998; *D*, 26 February 1998. Paving berm, marked with yellow arrow in *C* and *D*, was laid down to keep water out of fractures.

Figure 4. Development of head scarp A in driveway, views to northeast (see Map 2 for location). Yellow arrow in each photograph markes same corner of concrete slab. *A*, Early stage of landslide development, 11 February 1998; *B*, 20 February 1998; *C*, 22 February 1998; *D*, 21 March 1998.



Topographic base from USGS 7 1/2-minute La Honda quadrangle

Figure 1. Location map of La Honda with 1998 Scenic Drive landslide (shown in red on right). 1998 Recreation Drive landslide shown in blue; 1974 Cañada Vista landslide shown in yellow.

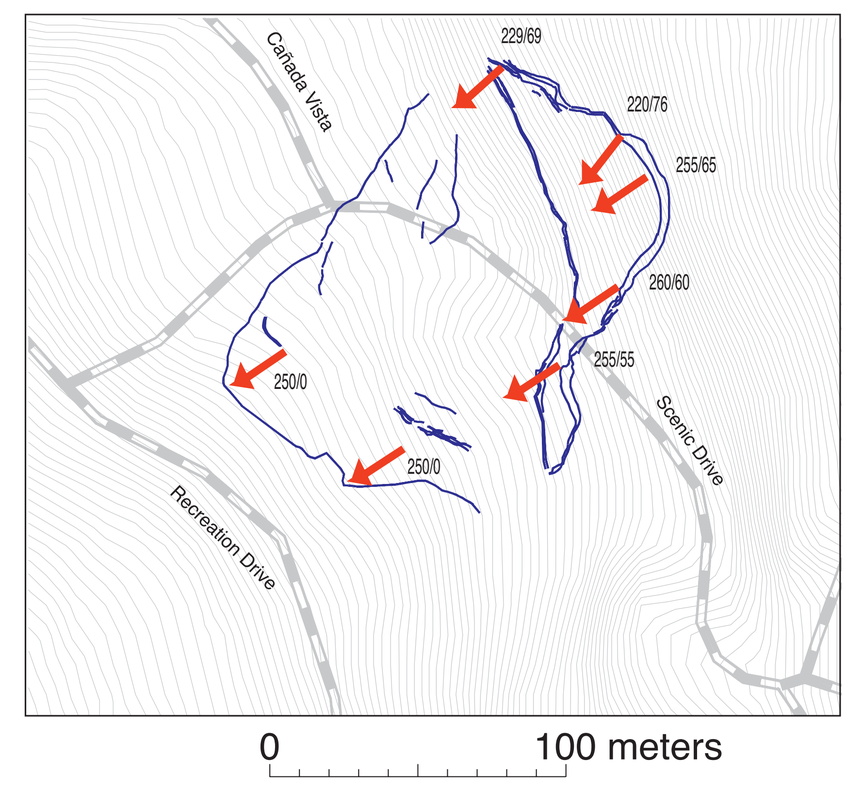


Figure 6. Scenic Drive landslide (shown in blue) and trend of displacement vectors (shown in red arrows; azimuth and plunge in degrees). One-foot contour interval generated from 10 m DEM's. Vectors measured 26 February 1998. Road locations from USGS 1:24,000 DLG, UTM projection.

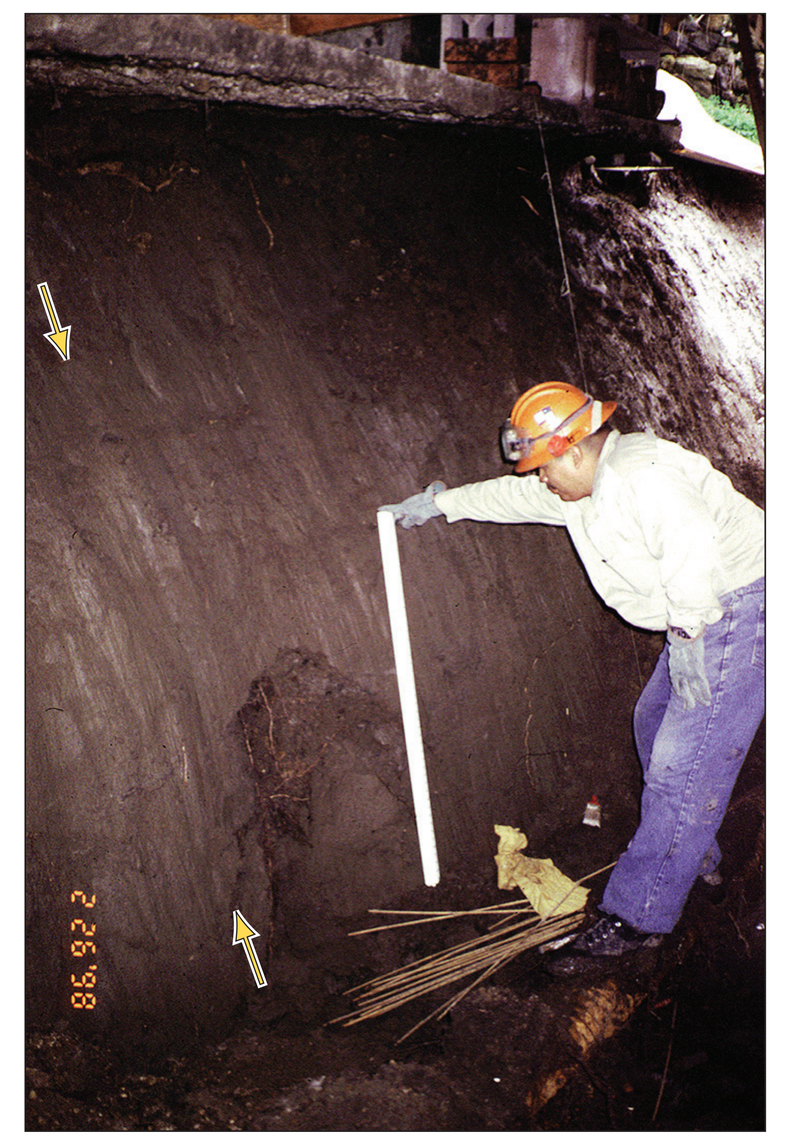


Figure 7. Slickenlines (striae highligted, for example, between yellow arrows) formed by scraping during slippage along head scarp A (see Map 2 for location), view to northeast. Photographed 26 February 1998.

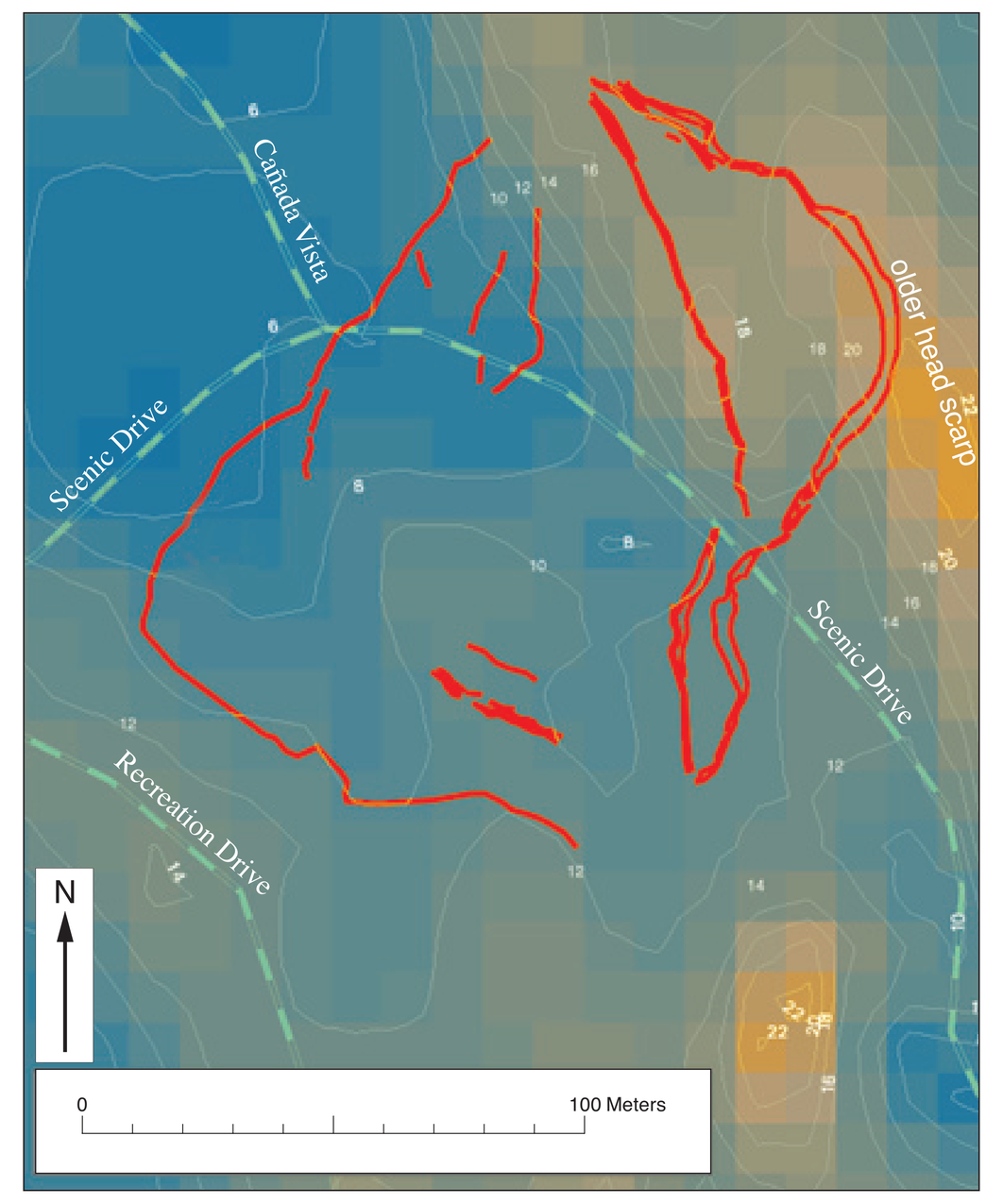


Figure 8. Map showing variation in slope (in degrees) of ground surface prior to 1998 landslide activity. Boundaries of 1998 Scenic Drive landslide (red lines) shown for reference. Slope angles generated from USGS 10 m digital elevation model (DEM). Contours (white lines) mark 2 degree intervals. Blue, low slopes; yellow, steep slopes.

Figure 9. Scenic Drive landslide toe (bulge in ground surface marked by diagonal red arrows). View to west; photographed 21 March 1998.

Figure 12. Graben that formed along axis of "Lower ridge" of Scenic Drive landslide . View to west; photographed 21 March 1998.

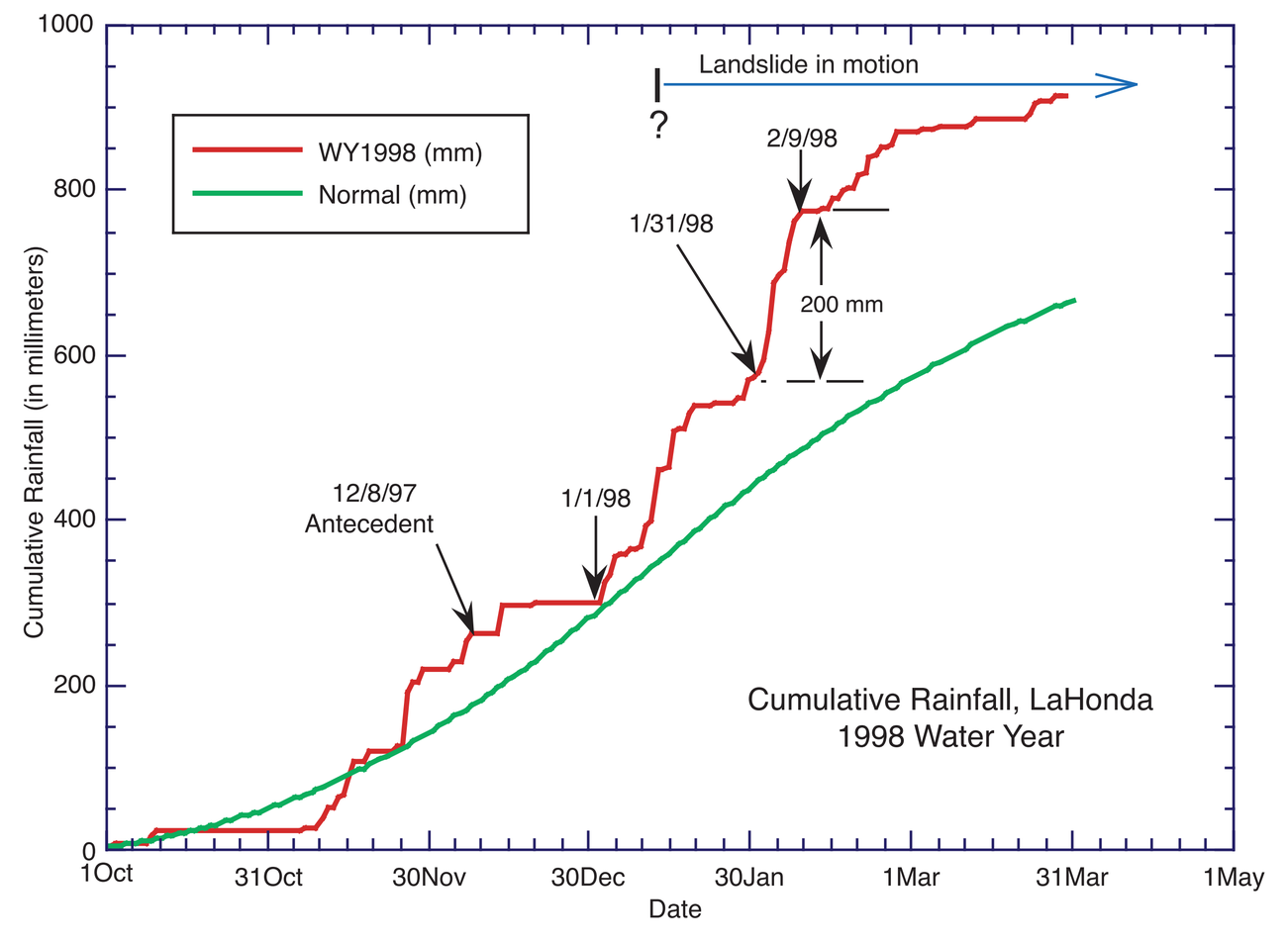


Figure 13. Plots of rainfall accumulations (in mm) in La Honda for the 1997-98 rainfall season (in red) and, for comparison, the long-term average, or "normal" conditions (in green). The 1997-98 rainfall data are from the National Weather Service Forecast Office in Monterey, CA; the long-term data were compiled from daily rainfall records from the National Climate Data Center in Ashville, N. C.

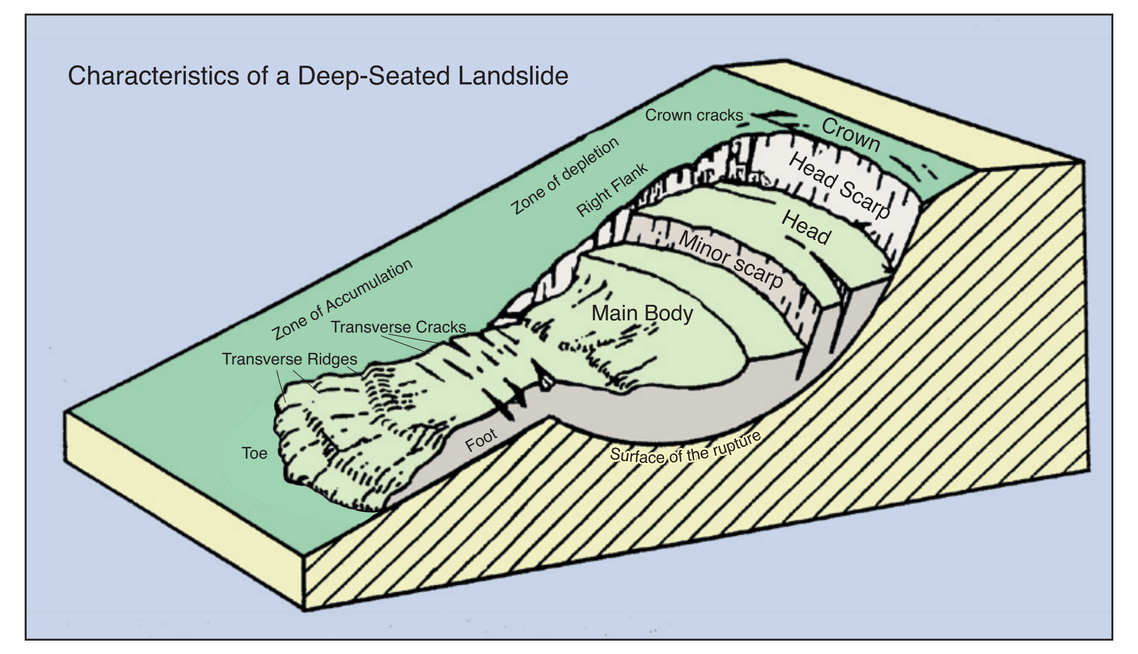


Figure 2. General shape and appearance of a landslide and the nomenclature used (from Eckel, 1958).

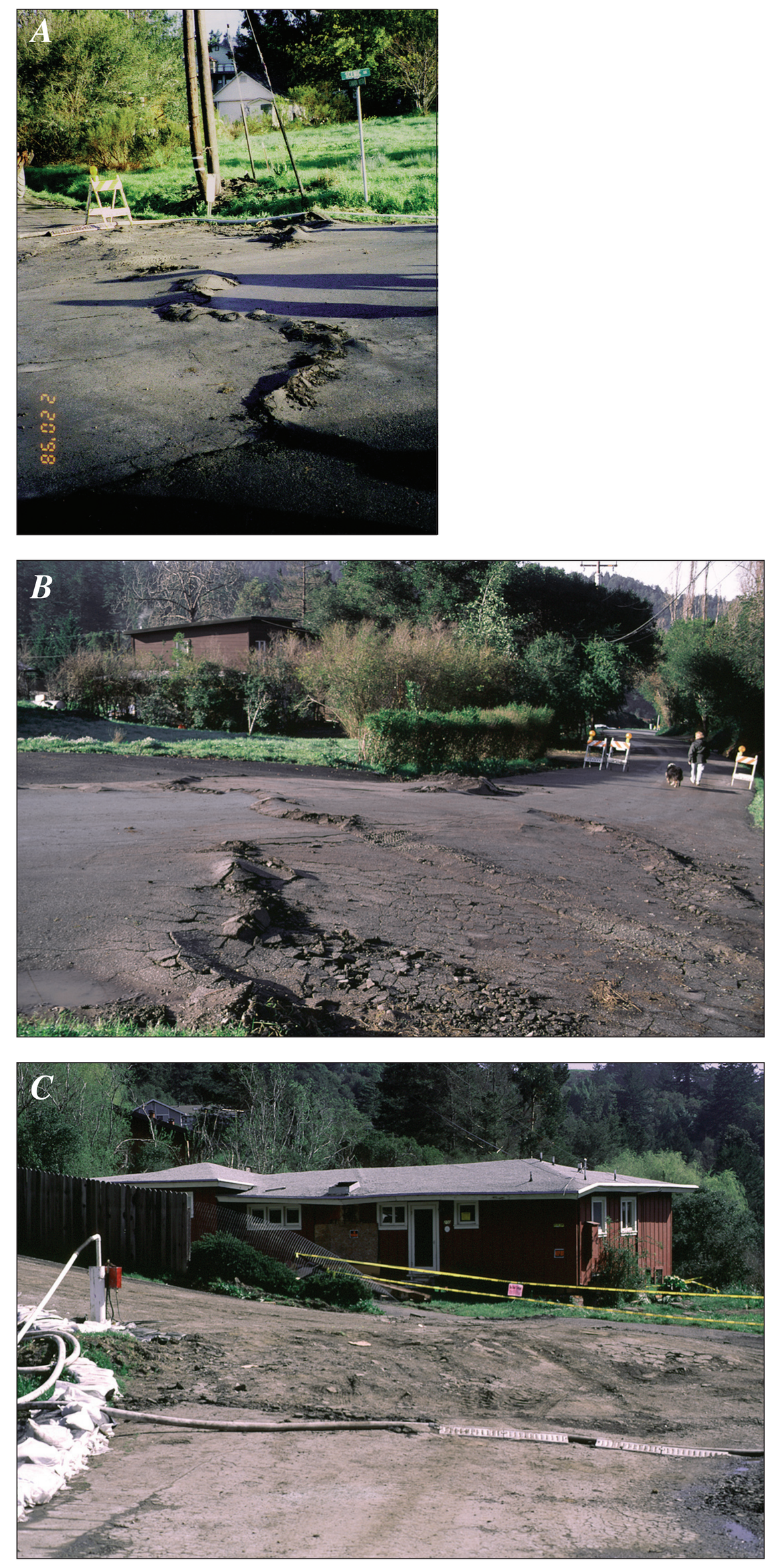


Figure 10. Development of right margin of Scenic Drive landslide at intersection of Scenic Drive and Cañada Vista (see Map 2 for location). *A*, Minor surface cracks present during early stage of landslide development, view to northeast, 20 February 1998; *B*, View to southwest, 28 February 1998; *C*, View to southeast, 21 March 1998.

Figure 11. Development of Scenic ridge, an antiform with a backthrust, thrust II, marked by yellow arrow (see Map 2 for location). *A*, Early stage of antiform development, notice nearly planar road surface, view to south-west, 20 February 1998; *B*, Enlarged backthrust, arrow, and uplifted road, view to southwest, 22 February 1998; *C*, Greatly uplifted road, people to right and left of arrow for scale, view to southeast, 21 March 1998.

SCENIC DRIVE LANDSLIDE OF JANUARY–MARCH 1998, LA HONDA, SAN MATEO COUNTY, CALIFORNIA

BY

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