BLUEBIRD CANYON LANDSLIDE, LAGUNA BEACH, CALIFORNIA

Robert Sydnor, County of Orange

Introduction

On October 2, 1978, four acres of a densely populated suburb of Laguna Beach became involved in a large block-glide landslide. Twenty-one residential structures were destroyed along with nearly 800 lineal feet of City roads. Ultilities within the streets were severed in many places. Despite severe property damage, no one was hurt. Total damages are estimated to be at least $15 million. About sixty families were evacuated during the first few days, although a few outside of the active slide were able to re-occupy their homes by the end of the first week.

The County of Orange was asked to help City officials on an informal basis through a request from the County Board of Supervisors. By the end of the first week, the City had selected their own full-time geologic consultants, Leighton and Associates of Irvine.

Road Log Description

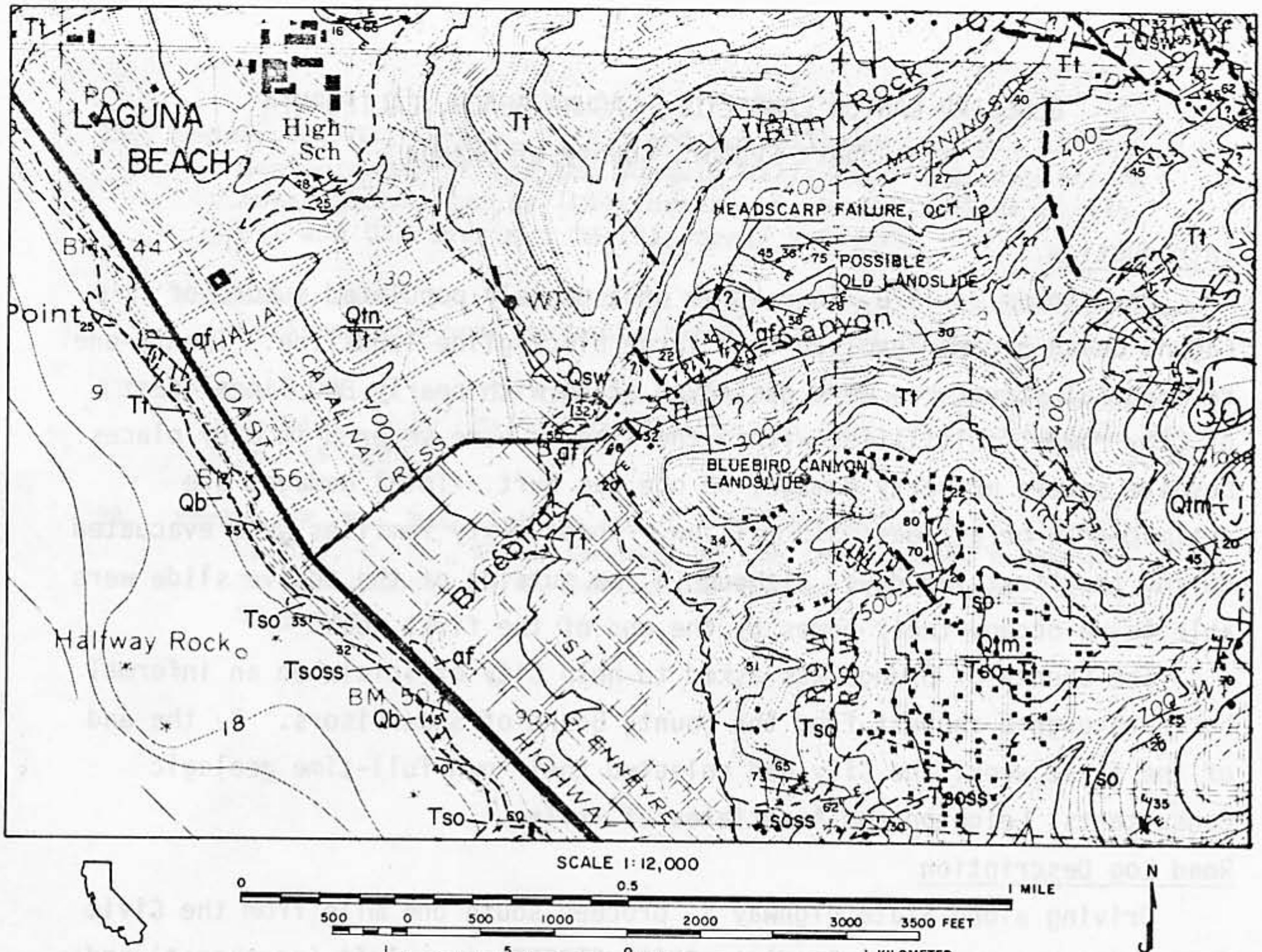
Driving along State Highway 1, proceed south one mile from the Civic Center (at Laguna Canyon Road) to CRESS STREET, turn left (northeast) and continue one-half mile to the mouth of Bluebird Canyon. Continue past the small city park about one-quarter mile and park along Bluebird Canyon Road. The landslide is the vacant area on the flank of the ridge to the northwest of Oriole Drive. (See Figure 1.) Some of the area has been fenced and closed by the City police to exclude sightseers and protect private property, so please respect posted signs.

Another good birds-eye view of the landslide can be obtained from Summit Drive on the crest of the ridge to the southeast of Bluebird Canyon.

Initial Emergency Measures

Following the October 2, 1978 landslide movement, the initial work of the geologists was directed towards the immediate structural damage to residential homes. There was intense pressure due to national television and newspaper coverage, distraught homeowners, and thousands of sightseers. A rough geologic map was prepared by the first day using a planimetric tract map as a base and a geologic cross section was measured by tape and Brunton compass methods. The engineering geologist and the City Building

Sydnor, Robert H., 1979, Bluebird Canyon Landslide, Laguna Beach, California, *in* Fife, D.L., *editor*, Geologic Guide of San Onofre Nuclear Generating Station and adjacent regions of southern California: American Association of Petroleum Geologists, Pacific Section AAPG Guidebook #46, p. 25-37.



SYMBOLS

Contacts; dotted where concealed; dashed where approximated; queried where inferred; solid where located with certainty.

Faults: dotted where concealed; dashed where approximated; queried where inferred; solid where certain; arrows show direction and numbers show amount of dip of fault plane and fault striations; U=upblock relative to downblock - D.

24 Attitude of bedding

24 E Attitude of bedding taken from excavation

Vertical bedding

78 Attitude of shear surface

78 E Attitude of shear surface taken from excavation

Vertical shear surface

80 Attitude of joint surface.

Qtm/Tt Developed area of artificial cut and fill with surficial unit thinly overlying bedrock unit

Bedrock landslide; arrows indicate direction of failure; scarp hachured where apparent; queried where uncertain; superimposed where failure has occurred on older landslide debris

EXPLANATION

SURFICIAL UNITS *

QUATERNARY

Holocene

- af — Artificial fill and cut areas (shown superimposed over rock units) af=mappable artificial fill
- Qsw — Slopewash debris
- Qb — Beach sediments; Qbs - mainly sand; Qbg - mainly gravel; Qbs+g - mainly sand & gravel
- Landslide debris

Pleistocene

- Qtn — Nonmarine deposits on marine terrace deposits (subscripts indicate relative level with I the lowest).
- Qtm — Marine terrace deposits (without nonmarine cover).

BEDROCK UNITS *

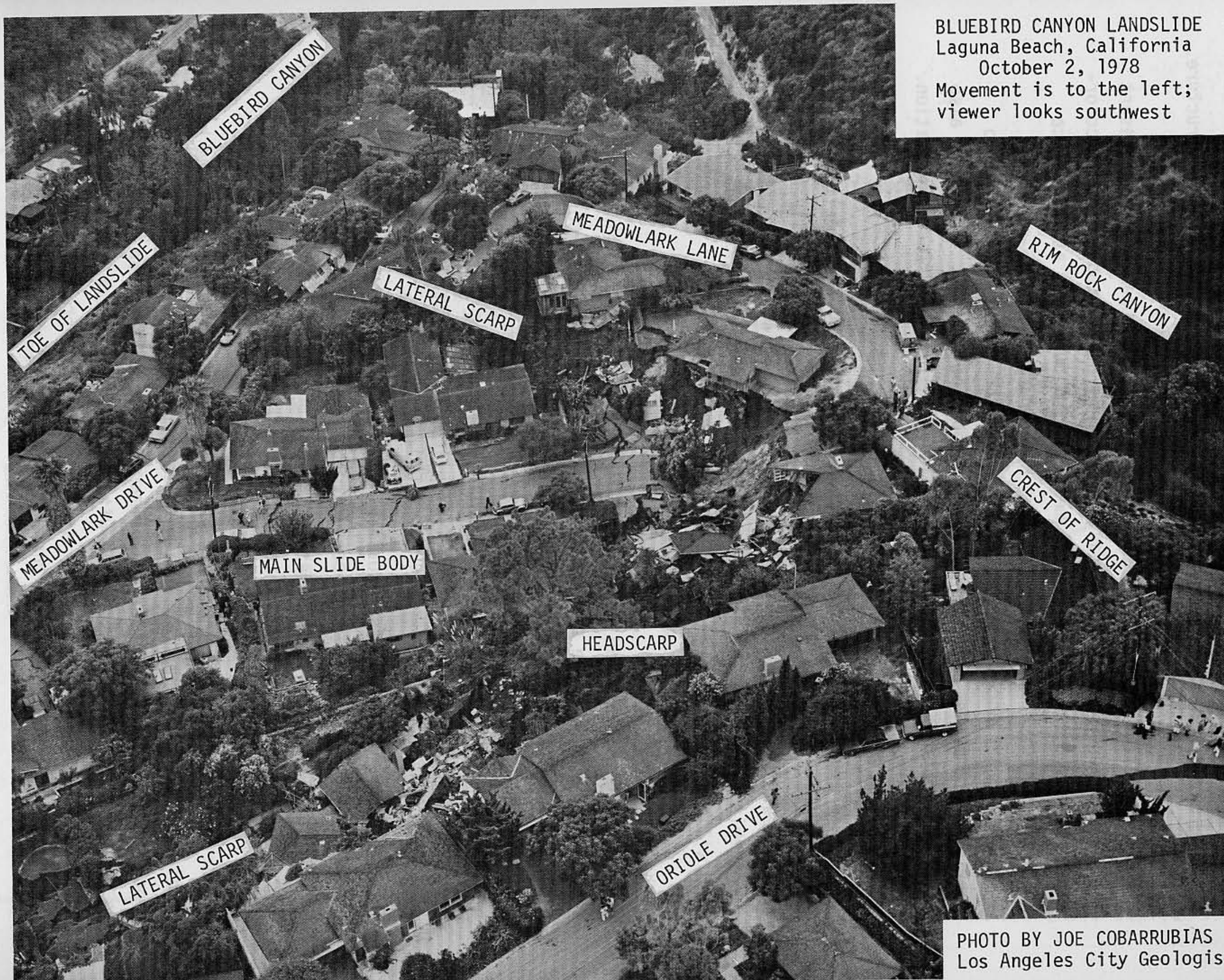
TERTIARY

Miocene

- Tso — San Onofre Breccia; Tso-ss - sandstone
- Tt — Topanga Formation

Figure 1. Bluebird Canyon landslide. *Map adapted from California Division of Mines and Geology Special Report 127, Plate 1.*

From California Geology, Jan. 1979



BLUEBIRD CANYON LANDSLIDE
Laguna Beach, California
October 2, 1978
Movement is to the left;
viewer looks southwest

PHOTO BY JOE COBARRUBIAS
Los Angeles City Geologist

Official went door-to-door among the residences and evaluated each structure. The residences were classified into three groups: Red - unsafe for occupancy; Yellow - doubtful and not suitable for occupancy at the present time; and Green - no immediate danger, home may be reoccupied. This color-coded map was displayed along with messages and bulletins at the police command post for review by the anxious homeowners.

A temporary access road was graded onto the intact slide block to retrieve automobiles, furniture, and household belongings. This road also provided access for a bucket-auger drilling rig for subsurface exploration.

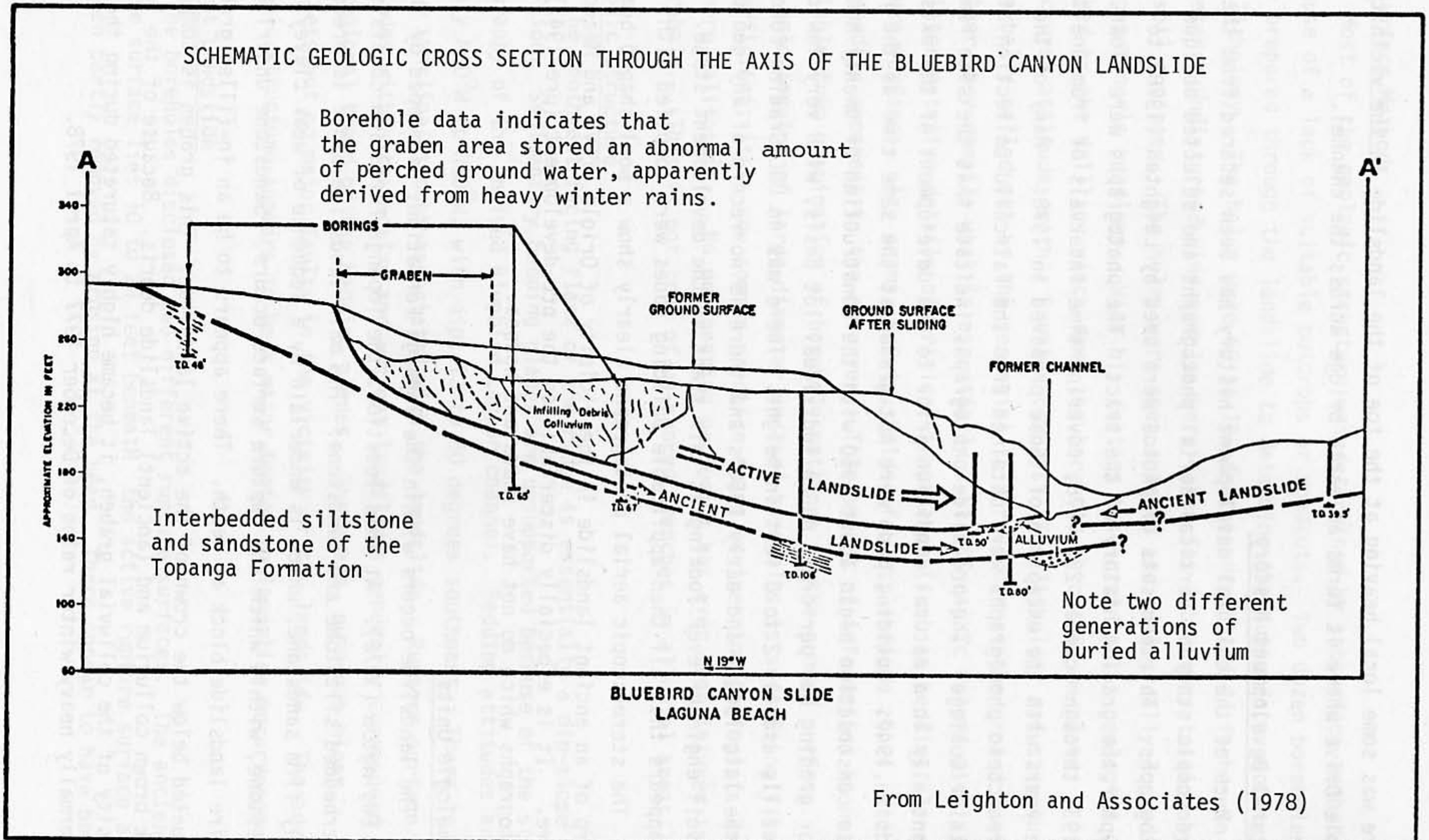
Causes of the Landslide

There appear to be four main factors contributing to landsliding: (1) rock weakness, (2) adverse geologic structure, (3) unusually high pore-water pressure above a plastic clayey surface, and (4) channel entrenchment of Bluebird Creek with erosion at the toe of an ancient landslide. Each will be explained in the following paragraphs.

Landslide Geomorphology

The active landslide lies on the flank of a ridge on the northwest side of Bluebird Canyon. The ridge flank is relatively gentle (6 to 8 degrees), with an abrupt change of slope (30 to 37 degrees) that decends to the canyon bottom. The maximum relief from the crown of the active landslide to Bluebird Canyon is about 120 vertical feet. The landslide is about 3.6 acres in size, about 490 feet long, 450 feet wide, and has an estimated volume of 290,000 cubic yards of earth. The thickness is variable from 50 to 70 feet. The slide moved about 50 feet horizontally and 20 feet downward. The duration of primary movement appeared to be about 40 to 60 minutes, with minor creep recorded for many days afterward.

This type of landslide is termed a "block-glide" or "rock-block" landslide because it moved as a relatively intact block along a fairly planar rupture surface. There was surprisingly little damage to some homes within the main slide block. Palm trees and power poles within the main block remained vertical after the primary movement had taken place; there was no backward rotation as associated with a rotational slump. The horizontal movement of the block essentially stopped when it overrode the canyon alluvium and was buttressed by the opposite wall of the incised canyon.



SCHEMATIC CROSS-SECTION A-A'

There was some local heaving at the toe of the landslide in the vicinity of Oriole Drive where it forms an earth bridge across the channel.

Cultural Development History

Much of the cultural development history has been secured from the stereoscopic study of vertical aerial photographs and selected oblique photographs. Thirteen sets of photos were used by Leighton (1978) to decipher the grading history of the tract. The photographs were flown in 1931 through October 23, 1978, covering time intervals of from one to nine years with the exception of those prepared in 1978. Many of the older stereoscopic photographs were obtained from the Fairchild Collection at Whittier College. The pre-slide photographs indicate that the site remained essentially in a natural condition prior to the development of the existing roads in 1947. Building pads were not graded at the same time as the roads. House construction began about 1950 with the construction of twenty homes. Minor grading was performed on an individual lot basis, with very low cuts and fills usually 2 to 6 feet in height. There was no UBC Grading Code in the late 1940's and early 1950's and there is no record of any geologist or soil engineer ever looking at this tract at the development stage. It appears that all then-applicable building codes were complied with.

The stereoscopic aerial photographs clearly show a bowl-shaped head scarp of an ancient landslide in the vicinity of Oriole Drive and Meadowlark Drive. It is especially discernable on the pre-development (pre-1947) photographs which do not have roads and houses.

Lithologic Units

The landslide occurs within the Topanga Formation, as mapped by Tan and Edgington (1976). At this location, the Topanga Formation consists of interbedded siltstone and sandstone. The main landslide block is predominately firm sandstone, which is underlain by a sequence of weak clayey siltstone, within which the rupture surface occurs. Sandstone underlies the entire landslide block at depth. There appears to be an in-filled graben situated below the crown of the active landslide. This graben is composed of dark brown colluvium and (ancient) landslide debris. Because of the low-density of the colluvial graben, it became highly saturated during the abnormally heavy winter rains of December 1977 to April 1978.

Subsurface Methods

Most of the geologic structure was determined by subsurface methods because of a lack of suitable outcrops or roadcuts. Two dozen boreholes were prepared through the landslide to determine the subsurface geometry and lithology. The holes were 60 to 106 feet in depth and 24 inches in diameter. Undisturbed ring samples were taken for laboratory testing by the soil engineer. The holes were then entered and geologically logged using a miner's headlamp. With his feet on a stirrup bar, a geologist was lowered by the drilling winch down the borehole to obtain in-place structural attitudes with a Brunton compass. The lithology and structure is verbally called out by the geologist to a recorder at the ground surface. Together they compile what is essentially a stratigraphic column with all the interpretative details of critical importance (such as bedding planes, rupture surfaces, clay seams, joints, folds, faults, seepage zones, etc.). All are readily apparent to the observer. This amount of information is not available from examination of borehole cuttings at the ground surface. Down-hole logging of large-diameter uncased boreholes is surprisingly safe and efficient; it is now common practice among engineering geologists in southern California. No engineering geologist has ever been injured in a borehole. (This is not true of un-shored trenches in alluvial areas.)

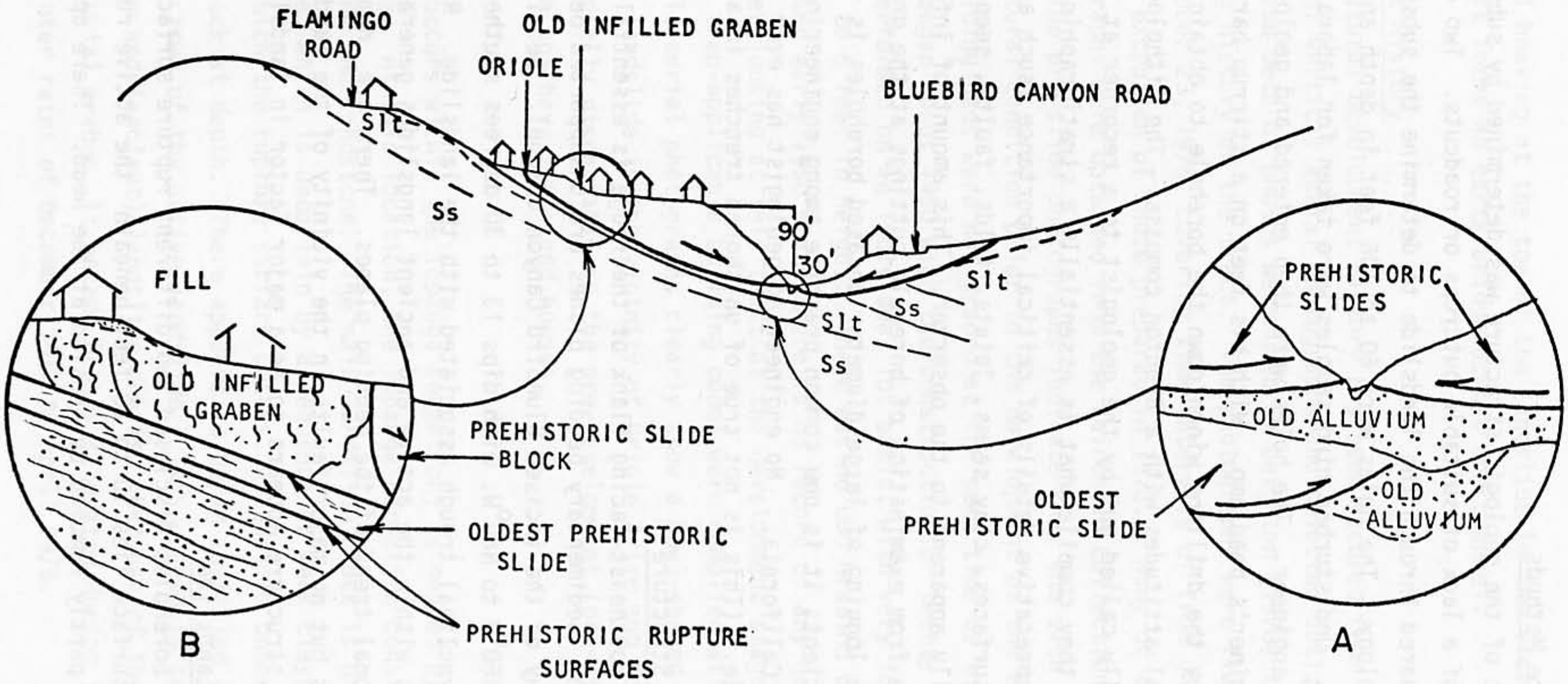
Geologic Structure

The southeast-facing flank of the ridge is essentially a dip-slope condition. Sedimentary bedding planes are unsupported because of the steep topography of the incised Bluebird Canyon channel. Bedding attitudes are roughly N60^{o}W to N80^{o}W, with dips 13 to 30 degrees southeast. There is a gentle synclinal trough associated with the landslide. Rupture surface attitudes within the active and ancient landslides generally correspond to the regional trend of the bedding planes. There are numerous minor faultlets but no major faults in the vicinity of the landslide. The adverse geologic structure appears to be a major factor in landslide occurrence.

Ancient Landslide

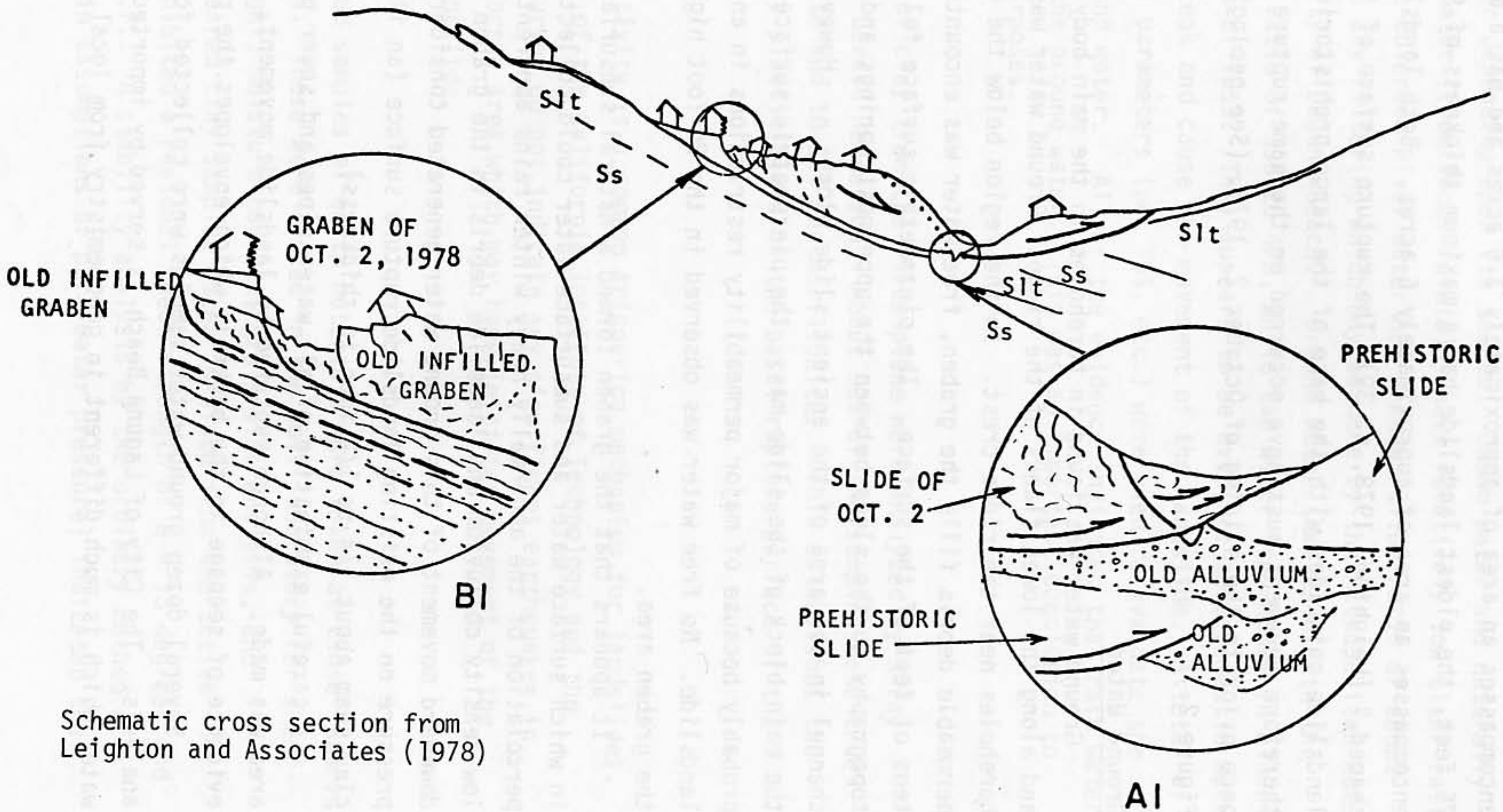
The boreholes disclosed two different rupture surfaces. The ancient rupture surface lies 10 to 20 feet beneath the active rupture surface and has been partly removed by erosion at the head. There appear to have been

KEY LANDSLIDE RELATIONSHIPS
PRIOR TO OCTOBER 2, 1978 SLIDING



Schematic cross section from
Leighton and Associates (1978)

KEY LANDSLIDE RELATIONSHIPS AFTER OCTOBER 2, 1978 SLIDING



Schematic cross section from Leighton and Associates (1978) at least <u>three</u> episodes of landsliding. "Whereas the active landslide encompasses an area of approximately 3.6 acres and has a maximum thickness 75 feet, the oldest landslide has a maximum thickness of 91 feet and encompasses an area of approximately 6 acres. Both landslides are horseshoe-shaped." (Leighton, 1978, p. 39) The rupture surface of the active landslide coincides with the base of the large prehistoric graben, and therefore movement must have occurred on the same rupture surface at least once prior to the sliding of October 2, 1978. (See geologic cross section, Figure 2.)

Ground Water

Ground water was found in boreholes in the main body of the landslide and along the lower flanks of the ridge. Ground water was not found in boreholes near the ridge crest. In the region below the headscarp where permeable debris fills the graben, free water was encountered within a few tens of feet of the surface. The piezometric surface follows the general topography to the slope between the uppermost borings and the Bluebird channel in the area of the ancient slide block. However, within the main block of the slide mass the piezometric surface is depressed, probably because of major permeability restrictions in and beneath the active landslide. No free water was observed in the 20-foot high headscarp above the graben area.

It appears that the graben formed a natural subsurface "catch basin" in which surface water and subsurface water could collect. Gradual percolation of the abnormally heavy winter rains apparently saturated the low-density colluvium and landslide debris in the graben area. Continued downward movement of this ground water generated considerable pore-water pressure on the existing landslide rupture surface (an illite-rich, plastic clay seam about 1/4 to 1/2 inch in thickness).

A careful examination of all water pipes and sewer pipes within the area was made. Although ruptured by landslide movement, no pipes had any evidence of seepage in the backfill which envelopes the pipes.

Several dozen ground-water samples were collected for laboratory analysis. The City of Laguna Beach is served by imported Colorado River water which is much different in geochemistry from local ground water.

The ratio of chloride ion to bromide ion is known to remain constant within ground water depending upon its source. Ocean water and naturally occurring ground water (from local rainfall) have relatively low Cl:Br ratios (about 300), while Colorado River water has a known Cl:Br ratio of about 1500-1800, despite any filtering which may be done by the Metropolitan Water District or the City of Laguna Beach. Ground water samples within the slide had a Cl:Br ratio of 338 to 478, while tap water from homes in Bluebird Canyon had a ratio of 1353. This appears to be evidence that domestic water supplies did not leak and cause the movement of the landslide. A total of twelve geochemical parameters (pH, TDS, etc.) were used to evaluate the origin of the ground water. All of the evidence indicates that rain water is the source of the ground water. This was an important conclusion to reach for legal purposes.

Clay Mineralogy

Four samples of clay from the slide plane were analyzed by X-ray diffraction by Dr. Gerald Henderson. About 90% of the samples were true clays, 42-68% illite and 10-25% montmorillonite. This establishes the existence of highly plastic clays on the basal rupture surface of the active landslide.

Seismic Activity

Earthquake activity is a common triggering mechanism for landslides. Earthquake records of the California Institute of Technology and the U. S. Geological Survey do not indicate any significant earthquakes in the southern California area which may have initiated movement of the Bluebird Canyon landslide.

Soil Engineering

Several hundred samples of earth materials were taken at close intervals in all 24 boreholes. These were tested in the soil laboratory for shear strength, unit weight, moisture content, grain-size analysis, and consolidation. Sheared clay samples taken in-place from the active rupture surface exhibited a residual shear strength of ϕ = 13 degrees and cohesion = 300 p.s.f. A stability analysis by the ordinary method of slices (with certain assumptions of pore-water pressure) indicated that the actual residual shear strength of the slide plane may be somewhat lower: ø = 9 degrees and cohesion = 100 p.s.f.

Remedial Measures

A large storm drain was placed in the canyon bottom to accomodate winter rains. The landslide toe had blocked the canyon and created a severe flood hazard. This was accomplished in November 1978 just a few hours before a severe storm hit the Laguna Beach area. It was a valiant round-the-clock effort by the grading contractor, Sukut Construction, Inc.

After the homeowners in the "Red Zone" had salvaged their furniture and appliances, the damaged homes were carefully dismantled by wrecking crews and the remains bulldozed into a debris pile and exported to the dump. The landslide was then cleared of all rubble and structural debris. Many of the medium-sized trees and shrubs were dug up, placed into crates or tubs, and trucked away to be recycled. Some ultilities to the remaining homes were reconnected by temporary surface pipes. Asphalt berms and sandbags were placed to intercept uphill surface water from winter rains.

The headscarp of the landslide was reduced from an unstable vertical cliff to a 2:1 (26 degree) graded slope. A system of 48 free-standing soldier piles (H-beams, each 40 to 50 feet deep) was placed in a horseshoe-shaped fashion above the headscarp during January 1979. This provided temporary protection for a shear key to be placed at the base of the headscarp.

On February 9, 1979, a small secondary landslide occurred above the original headscarp along Oriole Drive. This area was still within the ancient landslide. Prompt action by the consulting geologists and the grading contractor saved several homes on the uphill side of Oriole Drive.

At the time of this writing, the final disposition of the Bluebird Canyon Landslide is not known. The City wants to maintain the integrity of existing public roads and the ultilities within those roads for the remaining residences. There are about a dozen undamaged homes on the end of Meadowlark Lane and Meadowlark Drive which are essentially marooned without street access and ultilities. Much depends upon financial negotiations of City officials with Federal disaster agencies.

Acknowledgements

Appreciation is due to Lawrence R. Cann, Dr. F. Beach Leighton, Dr. Bruce R. Clark, Iraj Poormand, James E. Fisher, William R. Cotton, and James Knowlton who performed the geologic investigation of the Bluebird Canyon Landslide; to Fred Solomon, the City Manager of Laguna Beach; and to H. George Osborne, Director of the Environmental Management Agency of the County of Orange.

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