RECONNAISSANCE ENVIRONMENTAL GEOLOGY OF NORTHERN SCOTTSDALE

MARICOPA COUNTY, ARIZONA

by Troy L. Péwé, Jim Bales and Melissa Montz

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GEOLOGIC HAZARDS

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INTRODUCTORY STATEMENT*

Geologic hazards are natural geologic processes which continue to reshape the configuration of the land surface, and are called hazards only when man and his geologic environment change, interrupt, or get in the way of these processes. It is the purpose of this map to delineate areas of potential geologic hazards, where special precaution in planning and construction should take place to avoid danger to man's life and property. The activity by which these geologic processes operate can drastically change, and therefore, only the location, but not the timing, of geologic processes can be determined. Land developers, city planners, engineers, or anyone else interested in land use should be aware of these natural geologic processes and their potential detrimental effects. Processes that are potential geologic hazards in the northern Scottsdale area include slope instability, flooding, land subsidence and formation of earth fissures, and earthquakes.

Slope Instability

Unstable rock masses (boulders and large rock slabs) large enough to crush houses have in the past moved downslope on the steep slopes of the northern McDowell Mountains and hills and mountains projecting above Pinnacle Peak Pediment in the northern part of the area, and will do so in the future. This geologic hazard of slope instability must be seriously considered before undertaking any construction in the area. For protection of man and for aesthetic reasons, Maricopa County and the City of Scottsdale have hillside regulations (Scottsdale Hillside Ordinance) dealing with construction on the slopes and bedrock areas.

Slope instability refers to the tendency of earth materials to move downslope under the influence of gravity. Several types of potential instabilities occur, grouped under the general heading of landslides or mass wasting. On steep slopes mass wasting can and does occur naturally; on the more gentle slopes, the potential for landslides is increased by the undercutting of slopes and the misdirected flow of surface water by man. Generally, erosion is imperceptibly slow, though with certain rock types or deposits on steep slopes, erosional processes can be rapid and destructive. Granitic and basaltic bedrock areas are associated with boulder rolling because of the rounded nature of the boulders; rockslides, on the other hand, are associated with steep slopes of metamorphic rock in the higher mountains. Boulder falling or rolling is a very common type of downslope movement in granitic bedrock areas of the arid southwest, especially Arizona. The granitic outcrops of the steeper slopes of the northeastern part of the McDowell Mountains and the hills and mountains of the pediment are highly subject to boulder rolling. Rounded granite masses (boulders up to 20 ft (6.1 m) or more in diameter) move down the hillside and roll some distance out onto the gentle slopes. This is a common phenomenon in the area and is an ever-continuing process; boulders can crash down the hillside at any time.

Evidence that huge granite boulders have rolled down the steep slopes onto the gentle slopes is clearly indicated by the presence of the large rounded blocks at the base of the hills and on the gentle slopes. Some boulders have moved as much as 100-150 ft (30.5 to 45.7 m) horizontally as they tumbled from the cliff. There is no question that boulders have rolled down the slopes in the past; the question is whether the process of boulder rolling is continuing. Evidence that the boulder movement did not take place all at one time and is a continuing process exists. The evidence that many of the boulders moved many years ago is that they are greatly rounded and the surfaces are very rough from deep weathering. Archaeological features indicate that some boulders have been stable for hundreds of years. Elsewhere, the blocks of boulders have fracture surfaces that are not as weathered and the edges of the rocks are angular, indicating breakage and movement at a much later date. Geologically, it is possible to state that where boulders are now unstable they will eventually move, but like earthquakes, it is not possible to state just when this action (boulder movement) will take place. Movement may be tomorrow or 100 years from now.

Boulders and blocks move downslope when forces are such that they overcome the friction holding the rocks in place. This movement may result from forces pushing or rocking the boulders, such as earthquakes or blasting tremors caused by man; or, a steady force of the pull of gravity, aided by the removal or weakening of the friction holding the boulders in place. Although the Phoenix area has been relatively free of earthquakes since historic time, they have occurred in the geologic past and are probably one of the main causes for the movement of boulders downslope in the area.

The common and ever-present force of gravity probably causes most downslope movement in the long run. Gravity is most effective when friction between the boulders and the slope is reduced through weakening or removal of a weathered clay and silt layer which tends to hold boulders in place. Intense rains over a long period of time reduce friction by lubricating the clay layer. Most mass movement takes place during and after a rainy period.

Flooding

Severe floods do occur in the desert, contrary to common opinion, and an understanding of weather patterns, drainage basin, and stream channel characteristics permits an understanding of quantitative and qualitative overbank and sheet-type flooding characteristics. Alluvial fan morphology and age relationships can also help qualitatively delineate areas of general flooding in non-mountainous areas. This work does not include a study of flooding, but the uncolored part of the map represents areas most subject to flooding problems.

Land subsidence and earth fissures

Land subsidence is caused by a variety of natural and manmade processes. A common cause of man-induced land subsidence is fluid withdrawal, and for purposes of this study only the effects of groundwater withdrawal are considered. In parts of the Paradise Valley Basin the water table is now 550 ft (167.6m) below the surface. This is a lowering of 350 ft (106.7m) since 1950, through pumping of groundwater for agricultural and urban uses. With compaction of the dewatered sediments, the land subsides. About 2 miles (3.2km) south of the mapped area, in the vicinity of Shea Blvd., the ground in Paradise Valley has subsided about a foot, and on the west side of Paradise Valley in northeast Phoenix land has subsided 5 ft (1.5m) locally. It continues to subside there at the rate of 0.44 ft (.13m) per year. Land subsidence causes a variety of engineering problems, from reversal of sewage flow, hampering of canal flow, damage to subsurface utilities, to the collapse of well-casings.

Differential subsidence of the land, and subsequent compaction of the underlying sediments over a bedrock knoll or a fault scarp, may cause the ground to crack at the surface, forming a fissure. These are called earth fissures and are becoming widespread in southern and south-central Arizona. They occur in unconsolidated sediments, typically near the margins of mountains or outlying bedrock outcrops where groundwater levels have dropped from 200 to more than 450 ft (61 to 137.2m). The initial appearance of a fissure is a small, linear, hairline crack. Negligible vertical offset, and separation of both sides, suggests that fissures are of tensile origin. Most fissures are less than a mile in length and are generally perpendicular to the local drainage patterns. Interception of water erodes the initial hairline cracks into gullies as much as 15 ft (4.6m) wide and 10 ft (3m) or more deep.

Many fissures exist in some of the major basins south and west of Scottsdale; the first fissure in Paradise Valley was noted in January of 1980. Studies reveal that more fissures probably will appear in northeast Phoenix, and perhaps elsewhere. No detailed studies of land subsidence have been made in northern Scottsdale, but as the water table is lowered by excessive use of groundwater, land subsidence will occur. Indicated on the map are zones of buried bedrock fault scarps which may have important potential for earth fissure formation as the overlying unconsolidated sediments become compacted as a result of excessive groundwater withdrawal.

Earthquakes

Earthquakes are a result of ground movement along a fault with a sudden release of tension within the earth's crust. Numerous faults exist in the area, but no evidence exists that they have moved for at least 35,000 years, and therefore, they are classified as inactive. Slight tremors may not directly damage structures, but such tremors could instigate rock movement on unstable slopes and cause destruction of buildings on or near hillsides in the area.

Each geologic hazard has its own effect on the landscape and consequently on man's environment. Land users should be aware of these potential problems, and precautions should be taken, including adequate engineering studies and sound planning.

SELECTED REFERENCES

Christenson, G. E., Welsch, D. G., and Péwé, T. L., 1978, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-A (Geology) 1:24,000.

Christenson, G. E., and Péwé, T. L., 1979, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-D (Caliche) 1:24,000.

Christenson, G. E., and Péwé, T. L., 1979, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-I (Waste Disposal) 1:24,000.

Christenson, G. E., and Péwé, T. L., 1979, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-J (Construction Conditions) 1:24,000.

Cordy, G. E., Holway, J. V., and Péwé, T. L., 1977, Environmental geology of the Paradise Valley Quadrangle, Arizona: Unpublished report, City of Scottsdale, Arizona, 14 maps.

DuBois, S. M., and Smith, A. W., 1980, The 1887 earthquake in the San Bernardino Valley, Sonora: Historic accounts and intensity patterns in Arizona: Special Paper No. 3, Arizona Bureau of Geology and Mining Technology, 112 p.

Green, C. R., and Sellers, W. D., 1964, Arizona Climate: University of Arizona Press, Tucson, Arizona, 503 p.

Jachens, R. C., and Holzer, T. L., 1982, Differential compaction mechanism for earth fissures near Casa Grande, Arizona: Geological Society of America Bulletin, v. 93, no. 10, p. 998-1012.

Laustsen, D. C., 1974, Gravity methods applied to the geology and hydrology of Paradise Valley, Maricopa County, Arizona: Arizona State University unpublished Masters Thesis, 137 p.

Miller, R. D., 1973, Map showing relative slope stability in part of west-central King County, Washington: U.S. Geological Survey Map I-852A.

Péwé, T. L., 1978, Terraces of the lower Salt River Valley in relation to the late Cenozoic history of the Phoenix Basin, Arizona: in Burt, D. M., and Péwé, T. L., Guidebook to the geology of central Arizona, Special Paper No. 2, Arizona Bureau of Geology and Mineral Technology, Tucson, p. 1-46.

Péwé, T. L., and Larson, M. K., 1982, Origin of ground subsidence and earth fissures, northeast Phoenix, Arizona: City of Phoenix, Arizona, 98 p., 8 Appendices.

Schumann, H. H., and Poland, J. F., 1970, Land subsidence, earth fissures, and groundwater withdrawal in south-central Arizona, U.S.A.: International Association of Scientific Hydrology, v. 2, p. 296-302.

Sauck, W. A., 1975, Geophysical studies near subsidence fissures in central Arizona (abs.): EOS, American Geophysical Union Transactions, v. 56, no. 12, p. 984-985.

Sturgul, J. R., and Irwin, T. D., 1971, Earthquake history of Arizona and New Mexico, 1850-1966: Arizona Geological Society Digest, v. 9, p. 1-2.

Sumner, J. S., 1976, Earthquakes in Arizona: Field notes: University of Arizona, Bureau of Geology and Mineral Technology, v. 6, no. 1, p. 1-5.

United States Department of Commerce, NOAA, 1973, Earthquake history of the United States: Publications 41-1, p. 1-3.

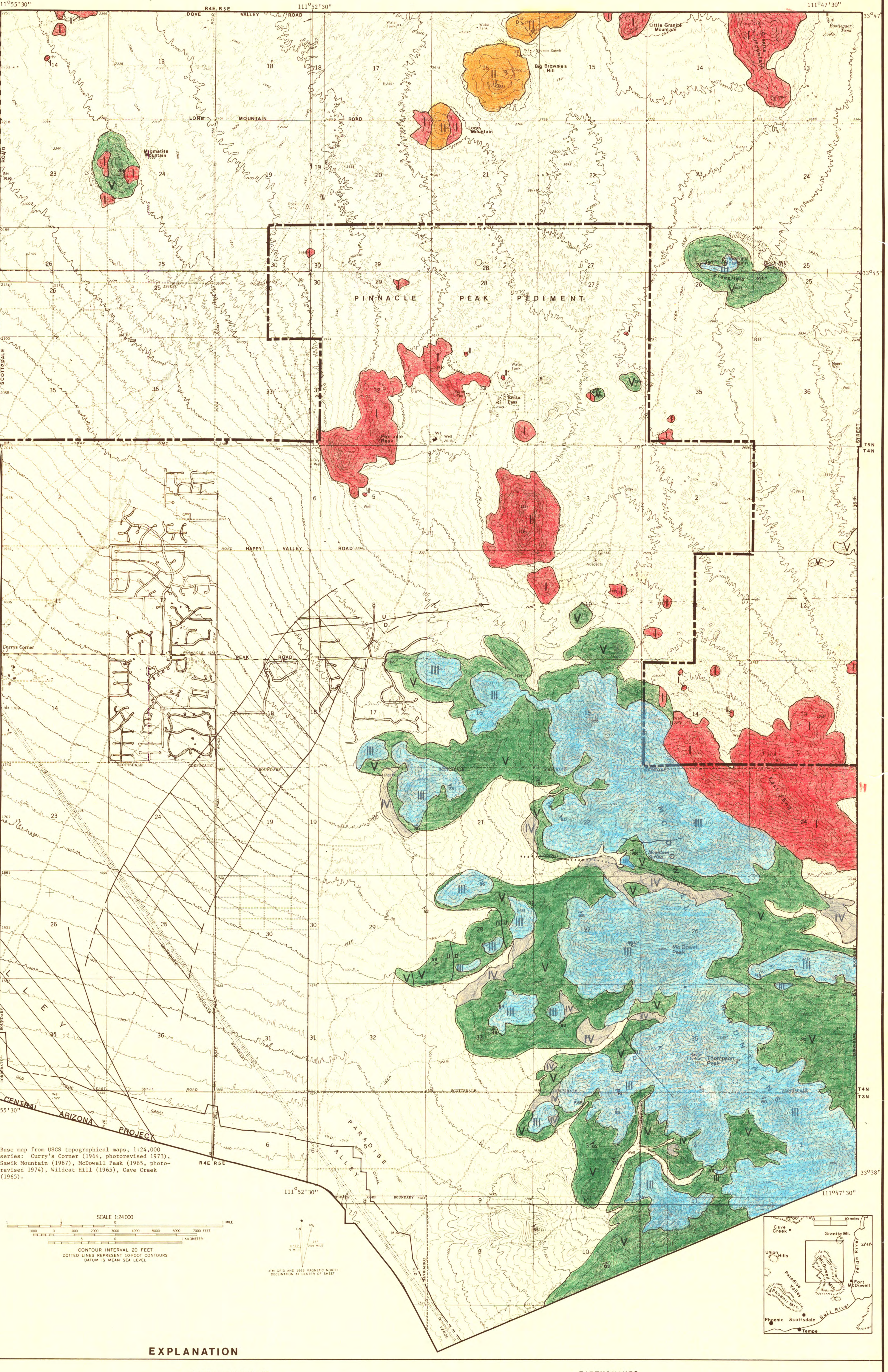
Welsch, D. G., and Péwé, T. L., 1979, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-C (Landslopes) 1:24,000.

_____1979, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-F(Material Resources) 1:24,000.

_____1979, Environmental geology of the McDowell Mountains area, Maricopa County, Arizona: University of Arizona, Bureau of Geology and Mineral Technology, Folio Series, Map GI-1-H (Excavation Conditions) 1:24,000.

Yerkes, R. F., Bonilla, M. G., Youd, T. L., and Sims, J. D., 1974, Geologic Environment of the Van Norman Reservoirs area: U.S. Geological Survey Circular 691-A, 35 p.

*This map involves a general investigation on a broad scale and does not preclude the necessity of individual site analysis.



Base map from USGS topographical maps, 1:24,000 series: Curry's Corner (1964, photorevised 1973), Sawik Mountain (1967), McDowell Peak (1965, photorevised 1974), Wildcat Hill (1965), Cave Creek (1965).

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

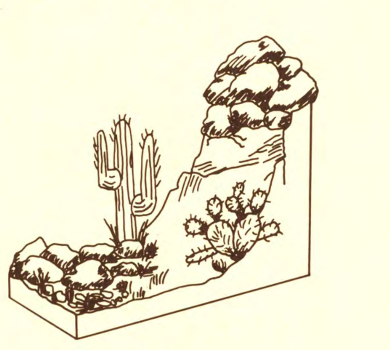
EXPLANATION

SLOPE INSTABILITY

Slope instability is the tendency for earth materials to move downhill under the under the influence of gravity. Several types of potential unstable slopes occur: boulder rolling, rock falls, and debris movement. Stability of a slope is in a continual state of change because of the geologic processes which act upon it and, therefore, only the potential areas of failure and not the rates at which these hazards take place can be outlined.

I — Granitic bedrock and boulder rollout areas. Erosion along joints forms subrounded masses 1 to 15 ft (0.3 to 5m) in diameter, capable of rolling down slopes greater than 15%.

II — Basalt and tuff bedrock and colluvium. Subrounded masses generally 1 to 4 ft (0.3 to 1.2m) in diameter roll or tumble from steep slopes or unstable talus debris, particularly if undercut or if boulders removed at bottom.

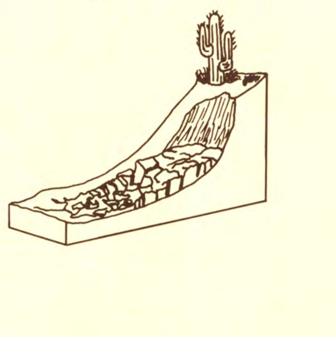


Rock falls

III — Blocky to platy metamorphicic rocks. Rock falls caused by loss of support provided by underlying rock or material on precipitous slopes greater than 45° (100%), rocks loose underlying support by erosion, earth vibrations, animal activities, wind, or other causes, blocks to 10 ft (3m) in diameter that literally fall and bounce down steep slopes, coming to rest on gentler slopes near base of mountains.

Debris movement

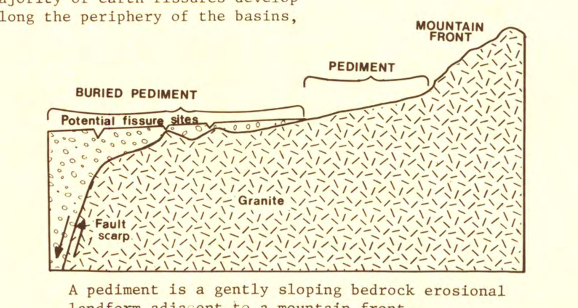
IV — Poorly compacted, unconsolidated colluvium and alluvium. Sediments unstable, particularly when saturated with moisture, generally on slopes greater than 10%; undercutting for roads and foundations or loading can cause loss of stability with downward movement of soil and rock.



V — Slope instability hazard weak to moderate.

EARTH FISSURES

Earth fissures are cracks in the ground surface, usually caused by differential ground subsidence resulting from ground water withdrawal and subsequent lowering of the water table. Analysis of earth fissure locations surrounding the Phoenix region indicates that the majority of earth fissures develop along the periphery of the basins, subparallel to mountain fronts. The locations correspond with steep gravity gradients associated with edges of bedrock shoulders and other bedrock irregularities, including buried faults.



A pediment is a gently sloping bedrock erosional landform adjacent to a mountain front.

FLOODING

The geologic hazard of overbank flooding, sheetwash, and flooding in general is not considered in this report and is more or less confined to the uncolored area of the map.

EARTHQUAKES

An earthquake is the trembling or shaking of the ground produced by rapid differential movement of rocks along a fault. It is caused by a sudden release of stress that has built up within the earth's crust. A number of faults are evident in the area. However, there is no field evidence indicating any movement at the surface within the last 35,000 years. The faults, therefore, would be classified as inactive (Yerkes and others, 1974). Numerous earthquakes have occurred in Arizona within historic time with the nearest, most recent occurring near New River, approximately 30 miles (48km) to the northwest of this area, on December 19, 1974. On the National Oceanic and Atmospheric Administration seismic rock map (the diagram below), potential moderate damage could be expected from an earthquake in this area and, therefore, is a factor that should be considered in design engineering of important structures.

MAP SYMBOLS

Contact, dashed where gradational.

Faults, dashed where inferred, dotted where buried.

Dip and strike of beds.

Dip and strike of foliation.