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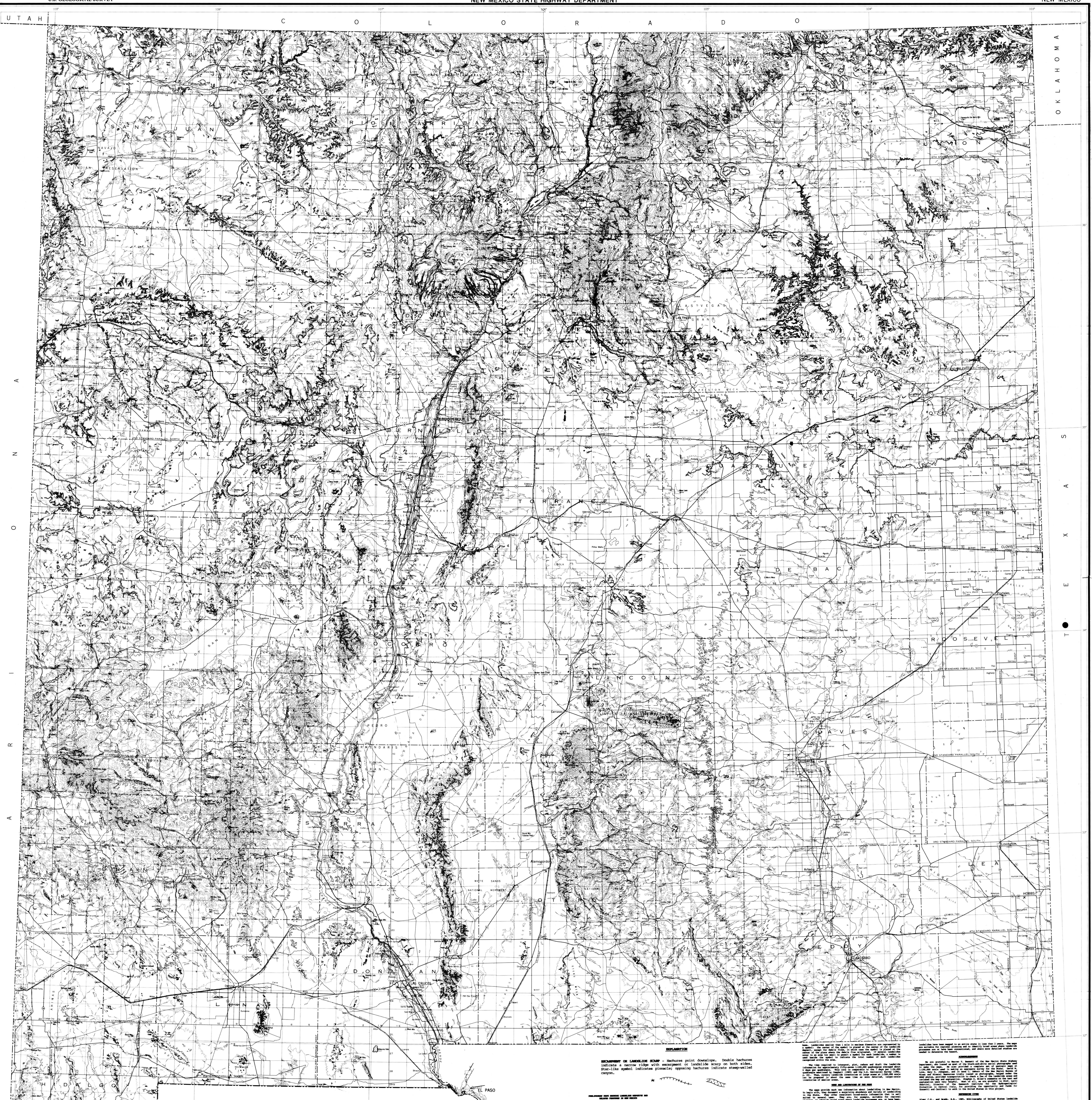

ESCARPMENTS AND LANDSLIDE SCARPS

PRELIMINARY MAPS SHOWING LANDSLIDE DEPOSITS AND RELATED FEATURES IN NEW MEXICO

By

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EXPLANATION

ESCARPMENT OR LANDSLIDE SCARP - Hachures point downslope. Double hachures indicate a narrow ridge with escarpment or landslide scarp on both sides. Star-like symbol indicates pinnacle; opposing hachures indicate steep-walled canyon.

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INTRODUCTION

These maps show the many places in New Mexico where there is evidence of past or present landslide movement. They are compiled from all readily available geologic and engineering literature and State reports, as well as systematic examination of aerial photographs. The four map sheets show deposits or features related to different kinds of landslide processes that pose different hazards, but constitute an inventory of landslide-related features that is the basic information upon which any evaluation of current or future susceptibility is based.

The maps result from a broad-scale inspection of the State. The broad scale provides an appraisal that is consistent over a large area but that lacks the detail necessary to detect either relatively small landslides or subtle or incipient large landslides. Consequently, the maps are suitable for use as a guide to potential landslide problems, BUT ABSENCE OF LANDSLIDE FEATURES ON THE MAPS DOES NOT IMPLY ABSENCE OF LANDSLIDE PROBLEMS.

BACKGROUND

The map project began in 1985 with discussions between Fausto Guzzetti of the Research Institute for Hydrogeological Protection in Central Italy and Earl Brabb of the U.S. Geological Survey about cooperative work on regional landslide analyses. They selected New Mexico as a project area because of the paucity of information about landslide processes in arid and semi-arid regions of the United States and Italy; because they wished to explore techniques for displaying landslide information at small (broad) scale that might be transferable to Italy and other areas; because they were curious about the time needed to prepare landslide inventory maps at small scale for an entire state; and because the New Mexico State Highway Department and Bureau of Mines and Mineral Resources offered to lend them the aerial photography needed for the study. Work began in October, 1985, and resulted in maps showing deep-seated and shallow landslide deposits in northwestern New Mexico (Guzzetti and Brabb, 1987) and a report by Brabb and others (1989) analyzing landslide distribution in relation to landslide overview maps of the United States, physiographic provinces, mean annual rainfall, and other aspects of climate.

In June of 1988, high-quality, infra-red color photographs for most of New Mexico not mapped by Guzzetti and Brabb were purchased by the U.S. Geological Survey and sent to Italy where Mauro Cardinali and Guzzetti began work to finish the remainder of the State. From October of 1989 until February of 1990, Cardinali worked full time in the United States with Brabb to complete the landslide inventory.

TERMINOLOGY

Landslide names used in this report follow the usage of Varnes (1978) unless otherwise noted, except that we use the term "landslide" to encompass all types of slope movement designated on the maps. We also use the term "toreva block" as defined by Reiche (1937) for a rock slump or series of rock slumps that have developed along the edges of mesas and buttes that are capped with a resistant rock, commonly basalt or sandstone. If the association of the slumped material with a resistant rock is not present or is not clear, we have identified the landslide simply as a slump. The term "scarp" as used here refers to steep slopes or cliffs adjacent to or within landslides and produced by landslide movement, and the term "escarpment" refers to steep slopes or cliffs apparently formed principally by differential erosion and not directly related to large landslides.

We distinguish landslides of different depths to separate the typically shallow and rapid processes of debris flow and rock fall which may kill people, from deep-seated landslides that commonly move slowly, destroying property but generally not killing people. The small scale (1:58,000) of most of the photos used for the analysis has probably prevented us from making this depth distinction accurately in several places, but our field observations indicate that the general depth distinctions we have made are valid.

Similarly, the small scale of most photos and the reconnaissance nature of mapping have probably prevented consistent and accurate distinction between bedrock, debris, and earth, as required for full description in the Varnes (1978) classification. Correspondingly, some of the landslides may not be properly classified as to materials involved. In general, bedrock, and especially resistant bedrock like basalt and sandstone, can be distinguished relatively easily on the photographs where it occurs on steep slopes and at high elevation. On gentle slopes at low elevation, especially if the bedrock is shale and other less resistant rocks, bedrock may have been mistaken for debris and earth.

METHODS USED

All of the landslide deposits shown on maps and in reports listed by Alger and Brabb (1985, p. 68-69) were plotted on 1:100,000-scale base maps. In particular, we had hoped that the landslide deposits mapped by geologists and engineers of the New Mexico State Highway Department (1971-1981), as a part of an aggregate resources study, would provide sufficient data that could be supplemented with information from aerial photographs. As we began checking these and other landslides, however, we became convinced that only a systematic evaluation of aerial photographs for the entire State could produce uniform results for landslide deposits and other information related to landslides, such as the location of escarpments, hummocky topography, and alluvial fans. Accordingly, we broadened our analysis by systematically identifying landslide and other features on aerial photographs and plotting them directly on the 1:100,000 base maps, modifying or adding substantially new information to the data from published reports.

Two substantially different kinds of aerial photographs were used for the mapping. Black-and-white aerial photographs flown in 1953 and 1954 at 1:31,500 scale by the Army Map Service (AMS) were the principal photographs used by Guzzetti and Brabb in the northwestern part of the State and in a few other areas (see index map). Color infra-red photographs at about 1:58,000 scale, flown in 1982 and 1983 under the auspices of the National High Altitude Program (NHAP) coordinated by the U.S. Geological Survey, were used for most of the remaining areas. This photography is well suited for broad-scale landslide analysis.

The resolution of NHAP photography is 3 to 5 ft, compared to 2 to 3 ft m for larger-scale, project photography, according to D. L. Light of the U.S. Geological Survey (verbal comm. 1990). We have identified debris flows that are probably as small as 5 ft in width, but the much greater length and other clues, such as association with alluvial fans, have helped with the identification of these narrow features. We have probably missed many landslides that have a maximum dimension of less than 50 ft.

The landslide information on the 1:100,000-scale base maps was reduced photographically to 1:500,000 scale and then drafted onto a stable mylar base. Landslides smaller than 1 mile in maximum dimension are represented by a symbol: the center of the symbol is placed at the center of the landslide deposit, except for debris flows, in which case the symbol is placed at the center of the place where the debris flow originated. If several landslides occur in an area too small to permit a symbol for each landslide, a number is used beside the symbol to indicate the total number of such landslides recognized within the area.

The time required to interpret, plot, reduce and draft the landslide information for approximately fifty-seven 1:100,000 quadrangles averaged about 6 days per quadrangle. This rate is comparable to the 7 days per 1:24,000 quadrangle mentioned by Campbell (1985) and the U.S. Geological Survey (1982, p. 22). Thus, cursory landslide inventories of large areas at 1:500,000 scale can be prepared in about the same time as more detailed, larger-scale inventories of smaller areas.

USES AND LIMITATIONS OF THE MAPS

The maps provide much new information about landsliding in New Mexico. To begin with, they document a surprising abundance and variety of landsliding in the State. They offer consistent broad-scale information that is well suited to several uses. They are, for example, suitable for regional planning, to identify broad areas where landslide processes are, or have been, concentrated and where more detailed studies are needed to determine the hazard. They can be used for the preparation of broad-scale landslide susceptibility maps and for studies of factors that control the spatial distribution of landslides. If landslides are shown at or near sites where development is planned, engineering geologists should be consulted to make certain that the extent of any landslide problem is recognized and that appropriate mitigation measures are considered.

The same qualities that make these maps suitable for some uses makes them unsuitable for others. The small scale of the maps and of the aerial photographs, the rapid pace of mapping, and the limited amount of field checking result in MAPS UNSUITABLE FOR HAZARD EVALUATION AT ANY SITE. Even landslide inventory maps at 1:24,000 scale, which are twenty times more detailed than the maps presented here, are considered unsuited for hazard evaluation at site scale (Smith, 1985).

The use of photography as old as 1953 and at scales as small as 1:58,000 has created an uneven landslide inventory. Many of the debris flows and other small landslides are detectable on the 1:31,500 photographs but not on the 1:58,000 photos. Landslides that have occurred after 1953 cannot be shown in the areas where only the 1953 photos were used. The field checking in 1987, however, indicates that these problems are minor in relation to the landslide information provided. Debris flows not detected on the 1:58,000-scale photos occur mostly among mapped debris flows and landslides, rather than in areas not recognized as having landslides. Also, most landslides appear to be older than 1953.

Deep-seated landslides are probably adequately represented on the maps, but shallow landslides (especially debris flows) and rock falls and topples are probably under-represented. Many of these features are probably large enough to pose serious hazards. MORE DETAILED LANDSLIDE MAPPING AND SITE-SPECIFIC STUDIES ARE NEEDED TO DETERMINE THE FULL EXTENT OF THE LANDSLIDE HAZARD IN NEW MEXICO.

Scarps and escarpments are mostly vertical or very steep rock walls that may topple or fall on adjacent areas. Talus slopes mantled with loose rocks and boulders downhill from these scarps and escarpments are especially hazardous. Boulders derived from the scarps and escarpments may roll and/or bounce onto nearby flat areas, but nearly all of the sites we investigated had boulders only on the talus slopes.

Some of the escarpments, especially those in the northern Sangre de Cristo Mountains, are associated with sackungen and large-scale, deep-seated distortions of steep-sided ridges (Varnes and others, 1989). The sackungen, according to Varnes and his colleagues, have the following characteristics: 1) Uphill-facing scarps on the slope, one to a few meters high, trending approximately parallel with topographic contours and commonly somewhat convex downslope in plan; 2) A graben or grabens along the ridge crest, commonly with closed contours and ephemeral ponds; 3) Double-crested ridges; 4) Bulging of the lower parts of the slopes; 5) Occurrence on the upper flanks of glaciated valleys; 6) Local relief more than 300 m; and 7) occurrence more common on massive and somewhat rounded ridges rather than on narrow ridges. Structures constructed across sackungen may be deformed or broken by slow movement of the slopes.

In summary, more than 9,000 landslides, thousands of miles of escarpments and scarps that may be hazardous, and other features associated with landslides have been mapped in an entire state in less than 2 years. The maps are suitable for regional planning and to identify broad areas where landslide processes are or have been concentrated, and where more detailed studies are needed to determine the hazard.

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REFERENCES CITED

Alger C.S., and Brabb, E.E., 1985, Bibliography of United States landslide maps and reports: U.S. Geological Survey Open-File Report 85-585, 119p.
Brabb, E.E., Guzzetti, Fausto, Mark, R.K., and Simpson, R.W., Jr., 1989, The extent of landsliding in northern New Mexico and similar semi-arid and arid regions, in Sadler, P.M., and Morton, D.M., editors, Landslides in a semi-arid environment: Riverside, Inland Geol. Soc., p. 163-173.
Campbell, R.H., 1985, Methods and costs for delineation of susceptibility to mud flows and other landslides, in Campbell, R.H., ed., Feasibility of a nationwide program for the identification and delineation of hazards from mud flows and other landslides: U.S. Geological Survey Open-File Report 85-276, p. C-1 to C-4.
Guzzetti, Fausto, and Brabb, E.E., 1987, Map showing landslide deposits in northwestern New Mexico: U.S. Geological Survey Open-File Report 87-70, scale 1:500,000.
Hansen, Andrew, 1984, Landslide Hazard Analysis, in Brunsden, D. and Prior, D.B., eds., Slope Instability: John Wiley & Sons, New York.
New Mexico Highway Department, 1971-1981, Geology and Aggregate Resources: Material Section, Santa Fe, New Mexico, scale 1:190.000.
Reiche, Perry, 1937, The toreva block - a distinctive landslide type: Journal of Geology, v. 45, no. 5, p. 538-548.
Smith, T.C., 1985, Landslide hazards in the southeastern part of the Petaluma dairy belt, Sonoma County, California: California Division of Mines and Geology Landslide Hazards Identification Map 1, scale 1:24,000.
Swanston, D.N. and Swanson, F.J., 1976, Timber harvesting, mass erosion and steepland forest geomorphology in the Pacific Northwest, in Coates, D.R., ed., Geomorphology and engineering: Stroudsburg, Pennsylvania, Dowden, Hutchinson & Ross, p. 199-221.
U.S. Geological Survey, 1982, Goals and tasks of the landslide part of a ground-failure hazards reduction program: U.S. Geological Survey Circular 880, 48 p.
Varnes, D.J., 1978, Slope movement, types and processes, in Schuster, R.L. and Krizek, R.J., eds., Landslides - analysis and control: Transportation Research Board, National Academy of Sciences, Washington, D.C., Special Report 176, p. 11-33.
Varnes, D.J., Radbruch-Hall, D.H., and Savage, D.J., 1989, Topographic and structural conditions in areas of gravitational spreading of ridges in the western United States: U.S. Geological Survey Professional Paper 1496, 28 p.

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.