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PRELIMINARY MAPS OF QUATERNARY DEPOSITS AND LIQUEFACTION SUSCEPTIBILITY, NINE-COUNTY SAN FRANCISCO BAY REGION, CALIFORNIA: A DIGITAL DATABASE

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INTRODUCTION

This report presents a preliminary map and database of Quaternary deposits and liquefaction susceptibility for the nine-county San Francisco Bay region, together with a digital compendium of ground effects associated with past earthquakes in the region. The report consists of (1) a spatial database of five data layers (Quaternary deposits, quadrangle index, and three ground effects layers) and two text layers (a labels and leaders layer for Quaternary deposits and for ground effects), (2) two small-scale colored maps (Quaternary deposits and liquefaction susceptibility), (3) a text describing the Quaternary map, liquefaction interpretation, and the ground effects compendium, and (4) this pamphlet. All parts of the report are digital; this pamphlet describes the database and digital files and how to obtain them by downloading across the internet.

The nine counties surrounding San Francisco Bay straddle the San Andreas fault system, which exposes the region to serious earthquake hazard (Working Group on California Earthquake Probabilities, 1999). Much of the land adjacent to the Bay and the major rivers and streams is underlain by unconsolidated deposits that are particularly vulnerable to earthquake shaking and liquefaction of water-saturated granular sediment. Map delineation of the different types and ages of Quaternary deposits supports evaluation of susceptibility to liquefaction, the immediate application of the work, but serves many other purposes as well. It provides a framework for interpreting the architecture and history of the Quaternary sedimentary basins, which is used in estimating earthquake shaking and modeling the groundwater system. The mapping is also useful in constraining the ages and histories of offsetting faults, in guiding geotechnical investigations, and in other engineering, geologic, and archeological applications.

This new map provides a modern and regionally consistent treatment of Quaternary surficial deposits that builds on the pioneering mapping of Helley and Lajoie (Helley and others, 1979) and such intervening work as Atwater (1982), Helley and others (1994), and Helley and Graymer (1997a and b). Like these earlier studies, the current mapping uses geomorphic expression, pedogenic soils, and inferred depositional environments to define and distinguish the map units. In contrast to the twelve map units of Helley and Lajoie, however, this new map uses a complex stratigraphy of some forty units, which permits a more realistic portrayal of the Quaternary depositional system. The two colored maps provide a regional summary of the new mapping at a scale of 1:275,000, a scale that is sufficient to show the general distribution and relationships of the map units but cannot distinguish the more detailed elements that are present in the database.

The report is the product of years of cooperative work by the USGS National Earthquake Hazards Reduction Program (NEHRP) and National Cooperative Geologic Mapping Program, William Lettis and & Associates, Inc. (WLA) and, more recently, by the California Division of Mines and Geology as well. An earlier version was submitted to the Geological Survey by WLA as a final report for a NEHRP grant (Knudsen and others, 2000). The mapping has been carried out by WLA geologists under contract to the NEHRP Earthquake Program (Grants #14-08-0001-G2129, 1434-94-G-2499, 1434-HQ-97-GR-03121, and 99-HQ-GR-0095) and with other limited support from the County of Napa, and recently also by the California Division of Mines and Geology. The current map consists of this new mapping and revisions of previous USGS mapping.

The report is preliminary because, although much of the mapping is at a scale of 1:24,000, for a third of the region it is at 1:100,000, including much of the core area, and another fifth meets less than 75% of the mapping criteria for the work (see part 3, Description of Mapping). Improvement of these parts of the map is the topic of ongoing work.

The report consists of eight numbered parts that are represented by digital files, most of which are provided in two or three different formats. The parts and files are described in DATABASE CONTENTS (below), and their packaging for user access is described in Presentation (below).

Parts 1, 2, and 3 are texts:

1. this pamphlet, including description of the Quaternary deposits, ground effects, and quadrangle index databases;
2. revision list, which lists the digital files as they are available over the Net and records version number and any revisions;
3. description of mapping, including description of mapping techniques and Quaternary units, of the liquefaction interpretation, and of the ground effects compendium (two color figures).

Parts 4, 5, and 6 are digital spatial databases and associated text layers:

4. Quaternary deposits and liquefaction susceptibility database: one database layer, one text layer;
5. ground effects database: three database layers (separate polygon layers for historic and Loma Prieta effects), one text layer;
6. quadrangle index database: one database layer.

Parts 7 and 8 are graphic plot files for map sheets 1 and 2 at a scale of 1:275,000:

7. map sheet 1: plot file of the Quaternary deposits map, including an index of the status of mapping and an explanation of map units;
8. map sheet 2: plot file of the liquefaction susceptibility map, including ground-effects localities.

The two colored maps are presented as digital plot files in PostScript and PDF format (image size 33 x 36 inches each). The PostScript map images (28-30 MB) can be used for viewing or plotting in computer systems with sufficient capacity, and the considerably smaller PDF files (6 MB) can be viewed or plotted in full or in part from Adobe ACROBAT running on Mac, PC, or UNIX platforms. The appearance of the maps in plots (colors and line weights) will depend on file type and the particular plotter that is used.

The five database layers are provided both as uncompressed ARC/INFO export files in Version 7 format and as ArcView Shape files. The database layers consist of the Quaternary deposits layer (which includes ratings for liquefaction susceptibility), the index of 7.5-minute quadrangles (which includes ratings for the status of mapping), and the three layers representing the compendium of earthquake ground effects. The label-and-leader text layers, which contain graphic elements, are provided only as uncompressed ARC/INFO export files. The full versatility of the spatial database is obtained by importing the ARC export files into ARC/INFO or an equivalent GIS package. Other GIS packages, including MapInfo and ArcView, may use either the ARC export or Shape files, although the Shape files do not retain the definition tables and do not include the text layers. The information in the definition tables is also listed in this pamphlet.

The spatial database was compiled in vector form over the past several years with versions 6 through 7.2 of ARC/INFO, a commercial Geographic Information System (Environmental Systems Research Institute [ESRI], Redlands, California), using the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991), and with MapInfo for part of the ground-effects database. The map plot files were assembled as graphics files in ARC/INFO from the spatial database and then converted to PostScript and PDF formats.

Acknowledgements

Digital compilation of the many 7.5-minute quadrangles involved was carried out over a period of several years, during which one or more quadrangles each were digitized by Andrew Barron, Gregg Beukelman, Joe Colgan, Jennifer Davis, Scott Graham, Marjorie Lucks, Tom May, David Ramsey, Carrie Randolph, Joel Robinson, Adam Soule, and Jim Thordsen. Digital compilation of the 0.5X1 degree quadrangles was done separately for the reports by Knudsen and others (1997) and Sowers and others (1998).

DATABASE CONTENTS

The report consists of digital files representing the eight parts of the database, most of which are presented in more than one format. The names of the files are unique designators based on the report identifier, of00-444, followed by part numbers and an extension indicating file type. Some of the files have been bundled in tape archive files (tar files: .tar extension) and the larger ones have been compressed with gzip, yielding a final .gz extension (see Presentation, below). An AML script (import.aml) is provided that will assemble the coverages and definition files in ARC/INFO from the export files. The files and their identities are as follows:

1. Open-File Pamphlet: The text of the open-file pamphlet (this text), which describes the database and how to obtain it.
    a. of00-444_1a.txt   ASCII file, 0.06 MB.
    b. of00-444_1b.ps   PostScript file, 0.8 MB.
    c. of00-444_1c.pdf   PDF file, 0.08 MB

2. Revision List: A list of the parts of the report (including bundled packages of parts), indication of the current version number for the report and in which version each part was last revised (if at all), followed by a chronologic list describing any revisions (see REVISIONS, below).
    a. of00-444_2a.txt   ASCII file

3. Description of Mapping: A 60-page text (two color figures) that describes the Quaternary deposits of the region, the 40 map units plus their subdivisions, the estimates of liquefaction susceptibility, the ground effects compendium, and the techniques and history of the work.
    a. of00-444_3a.txt   ASCII file, 0.2 MB. (No figures are included.)
    b. of00-444_3b.ps   PostScript file, 8.2 MB
    c. of00-444_3c.pdf   PDF file, 1.0 MB

4. Quaternary Deposits and Liquefaction Susceptibility Database: The data files representing the lines and polygons of the Quaternary deposits layer and associated definition tables (ARC export and ArcView Shape formats), and the annotation layer containing unit labels and leaders (ARC export format only). Note that the definition tables within the ARC coverage are not retained in the Shape files.
    a. of00-444_4a.e00.gz – Quaternary Deposits: a compressed ARC export coverage containing lines and polygons (11 MB, uncompresses to 46 MB). Import.aml will name this coverage sf-quat.
    b. of00-444_4b.e00 – Annotation: ARC export coverage containing unit labels and leaders (0.4 MB) scaled for graphic display at 1:275,000. Import.aml will name this coverage sf-qanno.
    c. of00-444_4c.tar.gz – Quaternary Deposits: ArcView line and polygon Shape files bundled as one compressed tar file (20 MB, uncompresses to 67 MB). When opened, the tar file yields:
        - line files: sf-qlns.dbf, sf-qlns.shp, and sf-qlns.shx
        - polygon files: sf-qpys.dbf, sf-qpys.shp, and sf-qpys.shx

5. Ground Effects Database: The data files representing the points, lines, and polygons of past earthquake ground effects (ARC export and ArcView Shape formats), and the annotation layer containing station numbers and leaders (ARC export format only).
    a. of00-444_5a.e00.tar.gz – Ground Effects: four ARC export coverages containing point, line, and polygon localities and station-number annotation and leaders for the historic and Loma Prieta datasets, bundled as one compressed tar file (0.07 MB, uncompresses to 0.6 MB). When opened, the tar file yields:
        - of00-444_5a1.e00: ARC export file containing point and line localities for both the historic and Loma Prieta datasets. Import.aml will name this coverage sf-effects.
        - of00-444_5a2.e00: ARC export file containing polygon localities for the historic dataset. Import.aml will name this coverage sf-efhspys.
        - of00-444_5a3.e00: ARC export file containing polygon localities for the Loma Prieta dataset. Import.aml will name this coverage sf-eflppys.
        - of00-444_5a4.e00: ARC export file containing station-number annotation and leaders for the whole effects database scaled for graphic display at 1:275,000 (1:100,000 for San Francisco). Import.aml will name this coverage sf-eanno.

b. of00-444_5b.tar.gz – Ground Effects: ArcView point, line, and polygon Shape files bundled as one compressed tar file (0.03 MB, uncompresses to 0.2 MB). When opened, the tar file yields:

- point files: sf-epts.dbf, sf-epts.shp, sf-epts.shx (the points of sf-effects)
- line files: sf-elns.dbf, sf-elns.shp, and sf-elns.shx (the lines of sf-effects)
- polygon files: sf-hpys.dbf, sf-hpys.shp, and sf-hpys.shx (the polygons of sf-efhspys)
- polygon files: sf-lpys.dbf, sf-lpys.shp, and sf-lpys.shx (the polygons of sf-eflppys)

6. Quadrangle Index Database: The data files representing the lines and polygons of the 7.5-minute quadrangle and status-of-mapping index.

a. of00-444_6a.e00.gz – Compressed ARC export coverage (0.2 MB). Import.aml will name this sf-qdgrid

b. of00-444_6b.tar.gz – ArcView line and polygon Shape files bundled as one compressed tar file (0.2 MB, uncompresses to 0.9 MB). When opened, the tar file yields:

- line files: sf-ilns.dbf, sf-ilns.shp, and sf-ilns.shx
- polygon files: sf-ipys.dbf, sf-ipys.shp, and sf-ipys.shx

7. Plot File of Quaternary Deposits Map: image size 33 x 36 inches.

a. of00-444_7a.ps.gz PostScript file, 5.9 MB, uncompresses to 27 MB

b. of00-444_7b.pdf PDF file, 5.6 MB

8. Plot File of Liquefaction Susceptibility Map: image size 33 x 36 inches.

a. of00-444_8a.ps.gz PostScript file, 6.2 MB, uncompresses to 30 MB

b. of00-444_8b.pdf PDF file, 5.9 MB

Presentation

The database files are provided individually (including Shape files packaged in tar files by equivalent ARC coverages) and some of the files are also packaged together in larger tape archive files (.tar). Most of the larger files have been compressed with gzip (.gz).

Separate Text Files: The revision list (of00-444_2a.txt) and the three formats of the open-file text (of00-444_1) and the Description of Mapping (of00-444_3) are provided separately, together with an abbreviated version of the ASCII text version of part 2 as a README. These text files in all three formats are also bundled in the database package.

Separate Database Files: The Quaternary deposits and liquefaction susceptibility database (of00-444_4), the ground effects database (of00-444_5) and the quadrangle-index database (of00-444_6) are provided separately in both ARC export (.e00) and ArcView shape (.tar) formats, as well as being bundled in the database package.

Separate Plot Files: The plot files for the Quaternary deposits map and liquefaction susceptibility map are provided separately in both PostScript and PDF format, as well as being bundled together in the plotfile package.

Database Package: The Quaternary deposits and liquefaction susceptibility layers (of00-444_4), the ground effects layers (of00-444_5), and the quadrangle index (of00-444_6) are packaged together in a single gzip-compressed tar file in both ARC (a) and ArcView shape (b) format. This package also includes text file of00-444_2a.txt and text files of00-444_1 and of00-444_3 in all three formats.

of00-444_9a.tar.gz   13 MB, uncompresses to 58 MB

of00-444_9b.tar.gz   23 MB, uncompresses to 77 MB

Plotfile Package: Plotfiles of the Quaternary deposits map and the liquefaction susceptibility map are packaged together in a single gzip-compressed tar file in both PostScript (a) and PDF (b) format.

of00-444_10a.tar.gz   12 MB, uncompresses to 57 MB

of00-444_10b.tar   12 MB

OBTAINING THE DIGITAL FILES

The database and image files can be downloaded from the Western Region Geologic Information Web Server or by anonymous ftp over the Internet.

1. Anonymous ftp over the Internet

The files for this report are stored on the Western Region publication server of the U.S. Geological Survey. The Internet address of this server is:

geopubs.wr.usgs.gov

Connect to this address directly using ftp or through a browser, log in with the user name ‘anonymous’, and enter your e-mail address as the password. This will give you access to all the publications available from the server. The files for this report are stored in the subdirectory:

pub/open-file/of00-444

2. From the Western Region Geologic Publications Web Server

The U.S. Geological Survey supports a set of graphical pages on the World Wide Web from which digital publications such as this one can be obtained. The Web server for digital publications from the Western Region is:

http://geopubs.wr.usgs.gov

This report can be reached by number (of00-444) through either the California or Open-File Reports 2000 options.

PROCESSING THE FILES

The database files require initial processing before they are usable, both to open bundled and/or compressed files and to import ARC export files.

Opening Tar and Gzip Files

Some of the files are assembled as tape archive files (tar files), and the larger files containing the databases and images have been compressed with gzip. Thus, gzip is required to uncompress the files, and a tar utility is required to open the tar files. Once extracted from the compressed tar files, the ARC export files can be imported into ARC/INFO using the utility import.aml that is included in the database package, or directly using the ARC import command.

The necessary utilities for uncompressing and extracting from tar format are available on-line:

gzip - This utility is available free of charge over the Internet from the gzip Home Page:

http://w3.teaser.fr/~jlgailly/gzip

or via links from the USGS Public Domain Software page:

http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/public.html

tar - This utility is included in most UNIX systems. Tar utilities for PC and Macintosh can be obtained free of charge via the Internet from Internet Literacy's Common Internet File Formats Web Page:

http://www.matisse.net/files/formats.html

Winzip - This commercial package runs on PCs and can deal with both gzip and tar files. An evaluation copy of WinZip can be downloaded from:

http://www.winzip.com/winzip/:

Importing the ARC Export Files

The ARC export files (.e00) can be converted to ARC/INFO vector databases (coverages) and associated INFO files by running the import.aml that is included in the database package. This will import the export files, assign standard names (see below), build polygon topology where appropriate (and if desired), and delete the export files once used (if desired). The 'build' and 'delete' options are enabled by answering YES to questions posed by import.aml. Running the aml again permits enabling those options previously rejected, but will not interfere with the results of earlier runs. The import routine checks for the presence of needed export files, for previously imported files, and for the need to build if that option is enabled. Run import.aml from the ARC prompt in the directory containing the export files:

ARC: &run import.aml	- run import.aml, answer YES/NO to the questions posed in the dialog area to choose options to import the export files, to keep or delete the export files, and to build the imported polygon coverages.

Note that the ARC coverages will be given standard names:

of00-444_4a.e00	will be named	sf-quat
of00-444_4b.e00		sf-qanno
of00-444_5a1.e00		sf-effects
of00-444_5a2.e00		sf-efhspys
of00-444_5a3.e00		sf-eflppys
of00-444_5a4.e00		sf-eanno
of00-444_6a.e00		sf-qdgrid

REVISIONS

Changes to any part of this report (parts are the numbered items described above in 'Report Contents' and listed in the revision list of00-444_1a.txt) may be made in the future if needed. This could involve, for example, fixing files that don't work properly, revising geologic details, adding new file formats, or adding other components to the report.

The report begins at version 1.0. Any revisions will be specified in the revision list and will result in the recording of a new version number for the report. Small changes will be indicated by decimal increments and larger changes by integer increments in the version number. Revisions will be announced and maintained on the Web page for this report on the Western Region Geologic Publications Web Server. Consult the revision list there to determine if a revision is significant for your purposes.

MAP COMPILATION

The Quaternary deposits database was compiled digitally in vector form in ARC/INFO as individual 7.5-minute (126) and 0.5x1.0-degree (2) quadrangles at scales of 1:24,000 and 1:100,000, respectively. The 1:100,000 materials were modified from previously released spatial databases for the San Francisco and Napa 0.5x1.0-degree quadrangles (Knudsen and others, 1997, and Sowers and others, 1998, respectively), and the 1:24,000 materials were variously modified from previous work or newly digitized, depending on the degree of remapping involved (see part 3, Description of Mapping). These many individual pieces were converted to UTM projection and assembled into a single regional layer. Remaining quadrangle boundary problems were resolved where possible, although some remain where the status of mapping differs across the boundary. The resulting spatial database retains the resolution of the input parts, some at 1:24,000, some at 1:100,000. Much of the fine detail in the spatial database is too small for legible portrayal at the regional scale of the colored maps (1:275,000).

The ground-effects database was compiled digitally in vector form from 1:100,000 and 1:24,000 materials, including relocation at 1:24,000 of 1:250,000-scale map features based on text descriptions of historic effects (see Appendix C of part 3, Description of Mapping). The Loma Prieta dataset was digitized directly in ARC/INFO, whereas the historic dataset was digitized in MapInfo and subsequently converted to ARC/INFO. Points and lines for the historic and Loma Prieta datasets were combined into a single vector layer, but the polygons could not be (some polygons overlap), and these remain separate.

The vector lines in the quadrangle database were generated automatically with high precision in ARC/INFO as a latitude/longitude grid, densified to a vertex spacing of 0.005 degrees along all the lines, and reprojected to UTM .

SPATIAL RESOLUTION

The digital database should not be used in ways that violate the spatial resolution of the data. Although the digital form of the data removes the physical constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. Use of the database at scales larger than 1:100,000 (or where appropriate, 1:24,000) may not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of this data.

The fact that the Quaternary deposits and ground effects datasets were assembled from maps of different scale, some at 1:24,00 and some at 1:100,000, means that information of resolution greater than 1:100,000 cannot be ensured in any particular part of the database. The resolution of the Quaternary deposits database by 1:24,000 quadrangle is described in part 3 and shown on Figure 3 of part 3 and on the index map of map sheet 1, and is encoded in the quadrangle index database in the COMPIL field and directly in the SCALE field. The quality of the original location of contacts is distinguished by line type. The ground effects locations have varying original quality, as described in the database, and were digitized from the published 1:100,000 and 1:24,000 (San Francisco) maps for the Loma Prieta earthquake and from 1:24,000 relocations of earlier historic localities. The quadrangle boundaries in the quadrangle index are accurate at 1:24,000.

DESCRIPTION OF THE SPATIAL DATABASE

The spatial database consists of five data layers (Quaternary deposits and liquefaction susceptibility, quadrangle index, three ground effects layers) as well as two text annotation layers, all in vector form. The database structure for the Quaternary deposits layer follows the ALACARTE data model, such that the primary line attribute is LTYPE and the primary polygon attribute is PTYPE. Appropriate definition tables are included (listed in Table 3), but the database departs from the data model described by Gautier (1999) for single geologic maps by including more than one topical attribute in the polygon attribute table (see table 6). The ground effects and quadrangle index databases also contain multiple topical attributes in their feature attribute tables. Both the Quaternary deposits and ground effects databases contain label-and-leader text annotation layers for use in graphic display at a scale of 1:275,000 (except for ground effects in San Francisco, which are designed for display at 1:100,000).

The ARC layers (coverages) are stored in UTM projection (table 1), whereas the Shape files are in decimal degrees of longitude and latitude, prepared by projecting and converting the primary UTM coverages.

Table 1. Map Projection

Projection	UTM (Universal Transverse Mercator)
Units	METERS
Zone	10
Datum	NAD27
Spheroid	CLARKE1866

The contents of the several database layers are described in terms of the points, lines, polygons, and text that compose them. Descriptions of the database fields (items) use the terms of table 2.

Table 2. Field Definition Terms

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B- binary integer, F- binary floating point number, I- ASCII integer, C- ASCII character string
N.DEC	number of decimal places maintained for floating point numbers

Quaternary Deposits Layer

The Quaternary deposits layer contains attributed lines and polygons and requires polygon topology for effective use. The lines and polygons are described here through their feature attribute tables and associated definition tables (table 3).

Table 3. Definition Tables Included as INFO Files in the ARC Coverage SF-QUAT

Table Name	Function
SF-QUAT.LN	defines line types (LTYPE)
SF-QUAT.UN	lists names of map units by PTYPE (polygon label)
SF-QUAT.QDEF	defines polygon LIQ values
SF-QUAT.LIQ	lists standard LIQ rating by PTYPE (map unit)

The attribute table for lines (SF-QUAT.AAT, table 4) contains the topical attribute field LTYPE, the eight different values of which are described in table 4 and in digital form as part of the sf-quat coverage in the INFO definition table SF-QUAT.LN.

Table 4. Structure of the Quaternary-Deposits Arc Attribute Table (SF-QUAT.AAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	
FNODE#	4	5	B	-	starting node of arc (from node)
TNODE#	4	5	B	-	ending node of arc (to node)
LPOLY#	4	5	B	-	polygon to the left of the arc
RPOLY#	4	5	B	-	polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
SF-QUAT#	4	5	B	-	unique internal control number
SF-QUAT-ID	4	5	B	-	unique identification number
LTYPE	35	35	C	-	line type

Table 5. Line Types Recorded in the Quaternary-Deposits LTYPE Field

This table lists the contents of the LTYPE definition table SF-QUAT.LN.

LTYPE	LDEF
contact, well located	depositional contact, location uncertainty less than about ± 100 m
contact, approx. located	depositional contact, location uncertainty greater than about ± 100 m
contact, concealed	depositional contact concealed beneath water, fill, or levee

county line	boundary of nine-county region, from 1:24,000 USGS DLGs and published paper topographic maps
map boundary	exterior boundary of 1:24,000 quadrangles composing the map area
scratch boundary	boundary without geologic attribute, here connecting mismatch of contacts or units at 7.5-minute quadrangle boundary
water boundary	boundary of open water from 1:24,000 USGS DLGs and published paper topographic maps
water boundary, 1800s	landward margin of tidal marsh bordering San Francisco Bay in the late 19th century, mainly from Nichols and Wright, 1971

The Quaternary-deposits polygon attribute table (SF-QUAT.PAT, table 6) contains the topical field PTYPE, values of which are map-label representations of the Quaternary map units (such as Qt). These labels and their equivalent unit names are listed in table 8 and in the INFO definition table SF-QUAT.UN, and are described in Appendix A of part 3. The codes for liquefaction susceptibility in the LIQ field are defined in table 7 and in the INFO definition table SF-QUAT.QDEF. Most susceptibility ratings are based on map unit (LIQ-SOURCE = 0), although some are assigned custom ratings (LIQ-SOURCE = 1) based on such local information as depth to ground water or historical occurrence of liquefaction. The standard correlations between map unit and susceptibility are listed in Table 8, in the INFO definition table SF-QUAT.LIQ, and in table 4 of Part 3, Description of Mapping.

Table 6. Structure of the Quaternary-Deposits Polygon Attribute Table (SJ-GEOL.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	
FNODE#	4	5	B	-	starting node of arc (from node)
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
SF-QUAT#	4	5	B	-	unique internal control number
SF-QUAT-ID	4	5	B	-	unique identification number
PTYPE	35	35	C	-	Quaternary unit label
LIQ	8	8	C	-	liquefaction susceptibility
LIQ-SOURCE	1	1	I	-	1 where custom LIQ value assigned, otherwise 0

Table 7. Meanings of liquefaction susceptibility codes in the LIQ field (SF-QUAT.PAT)

This table lists the contents of the LIQ definition table SF-QUAT.QDEF.

LIQ CODE (LIQ)	DEFINITION (QDEF)
VH	VERY HIGH
H	HIGH
M	MODERATE
L	LOW

VL	VERY LOW
W	WATER
NM	AREA NOT MAPPED

Table 8. Unit PTYPEs, Liquefaction Susceptibility Ratings, and Unit Names

This table lists in stratigraphic order the combined contents of the PTYPE definition table (SF-QUAT.UN) and the PTYPE/LIQ correlation table SF-QUAT.LIQ.

PTYPE	LIQ	NAME
		MODERN
af	L	Artificial fill
afbm	VH	Artificial fill over San Francisco Bay Mud
alf	H	Artificial levee fill
ads	VH	Dredge spoils
gq	H	gravel quarry
ac	L	Artificial stream channel
Qhc	VH	Modern stream channel deposits
		LATEST HOLOCENE
Qhfy	VH	Latest Holocene alluvial fan deposits
Qhly	VH	Latest Holocene alluvial fan levee deposits
Qhty	VH	Latest Holocene stream terrace deposits
Qhty1	VH	Younger latest Holocene stream terrace deposits
Qhty2	VH	Older latest Holocene stream terrace deposits
Qhay	VH	Latest Holocene alluvial deposits, undifferentiated
Qhfp	VH	Late Holocene alluvial floodplain deposits, undifferentiated
Qhfb	H	Late Holocene flood basin deposits
		HOLOCENE
Qhbs	VH	Holocene beach sand
Qhds	H	Holocene dune sand
Qhbm	H	Holocene San Francisco Bay Mud
Qhdm	H	Holocene San Joaquin/Sacramento Delta mud and peat
Qhb	H	Holocene basin deposits
Qhfe	H	Holocene alluvial fan-estuarine complex deposits
Qhff	H	Holocene alluvial fan deposits, fine facies
Qhf	M	Holocene alluvial fan deposits
Qhf1	M	Younger Holocene alluvial fan deposits
Qhf2	M	Older Holocene alluvial fan deposits
Qhl	M	Holocene alluvial fan levee deposits
Qhl1	M	Younger Holocene alluvial fan levee deposits
Qhl2	M	Older Holocene alluvial fan levee deposits
Qht	H	Holocene stream terrace deposits
Qht1	H	Younger Holocene stream terrace deposits
Qht2	H	Older Holocene stream terrace deposits
Qha	H	Holocene alluvium, undifferentiated

LATEST PLEISTOCENE TO HOLOCENE

Qds	M	Latest Pleistocene to Holocene dune sand
Qb	L	Latest Pleistocene to Holocene basin deposits
Qf	L	Latest Pleistocene to Holocene alluvial fan deposits
Ql	L	Latest Pleistocene to Holocene alluvial fan levee deposits
Qt	M	Latest Pleistocene to Holocene stream terrace deposits
Qa	M	Latest Pleistocene to Holocene alluvium, undifferentiated

LATEST PLEISTOCENE

Qpb	L	Latest Pleistocene basin deposits
Qpf	L	Latest Pleistocene alluvial fan deposits
Qpt	L	Latest Pleistocene stream terrace deposits
Qpa	L	Latest Pleistocene alluvium, undifferentiated

EARLY TO LATE PLEISTOCENE

Qmt	L	Pleistocene marine terrace deposits
Qmt1	L	Youngest (of 4) Pleistocene marine terrace deposits
Qmt2	L	Second youngest (of 4) Pleistocene marine terrace deposits
Qmt3	L	Second oldest (of 4) Pleistocene marine terrace deposits
Qmt4	L	Oldest (of 4) Pleistocene marine terrace deposits
Qop	VL	Early to late Pleistocene pediment deposits
Qof	VL	Early to late Pleistocene alluvial fan deposits
Qof1	VL	Younger early to late Pleistocene alluvial fan deposits
Qof2	VL	Older early to late Pleistocene alluvial fan deposits
Qot	VL	Early to late Pleistocene stream terrace deposits
Qoa	VL	Early to late Pleistocene alluvial deposits, undifferentiated
Qoa1	VL	Younger early to late Pleistocene alluvial deposits, undifferentiated
Qoa2	VL	Older early to late Pleistocene alluvial deposits, undifferentiated

PRE-PLEISTOCENE

br	VL	bedrock

The text annotation layer sf-qanno contains the unit labels and leaders used to label the Quaternary units on map sheet 1, Quaternary Deposits. All lines in the layer are leaders, with LTYPE = ‘leader’. All labels are level 1 annotation, 582 m high (map units), with $symbol = 20. The lines and labels are scaled and positioned for graphic presentation at a scale of 1:275,000.

Ground Effects Layers

The ground effects are assembled in three layers: a single layer of points and lines (sf-effects) for all the effects that can be represented by points or lines, including localities representing uncertain distribution of effects, and two separate polygon layers (sf-efhspys, sf-eflppys) for areas that can be delimited by boundaries, one each for the datasets for historic and for Loma Prieta effects. These must remain separate because some of the polygons overlap. The polygon layers require polygon topology for effective use. Information about the areas is attached to the polygons (label points), not to their bounding lines. Original station numbers from the two source documents (Youd and Hoose, 1978; Tinsley and others, 1998) are recorded in the database and are shown on the map to facilitate recovery of complete descriptions for each station. The locations, station numbers, and summary of effects are shown on map sheet 2, Liquefaction Susceptibility.

The historic localities of Youd and Hoose (1978) have been relocated at 1:24,000 based on the descriptions of the localities (see Appendix C in part 3, Description of Mapping), with the result that single Youd and Hoose localities can be represented by multiple localities in the database, all with the same original station number.

Accuracy ratings are reported as presented by Youd and Hoose (Table 9), and where different table entries for the same locality were given different ratings, these are aggregated for the locality (for example, ‘B,C’) and are assigned to each of the relocated occurrences for that locality. Accuracy ratings for the relocated occurrences (Table 10) are separately assigned. The resulting accuracy ratings for each map element in the ACC database field thus have two parts, a Youd-and-Hoose rating followed by a relocation rating, the two separated by a colon (for example ‘A:P’).

Table 9. Location-Accuracy Categories of Youd and Hoose (1978).

A	“a site that can be accurately relocated”
B	“a site that can be relocated to within a few kilometers and probably could be located more accurately with further investigation”
C	“a site where the information is insufficient to allow precise location”

Table 10. Relative Accuracy of Relocated Historic Effects

P	located to within 100 meters
Q	located to within 500 meters
R	located to within 1 kilometer
S	location is indefinite or approximate

Database fields (items) for the three ground-effects data layers are largely the same (Table 11). Exceptions involve the standard fields related to the specific coverage name and the kind of feature, and fields for polygon boundaries (lines) in the polygon layers sf-efhspys and sf-eflppys, which carry no topical attributes except SF. The meaning or content of the topical fields are described in Table 12. Note that the –ID number has been set to a unique value for each record within all three layers combined, and thus serves as a unique identifier for each map element in the database. The database fields LS-H through ABS separately record the presence of the various kinds of ground effects at each station. A value of 1 indicates presence (including the positive indication of the absence of effects – ABS), whereas 0 means that the effect was not indicated for the station.

Table 11. Ground-Effects Database Fields.

FIELD (ITEM)	WIDTH	OUTPUT	TYPE	N.DEC	FIELD VALUE
For points and polygons (.PAT)					
AREA	4	12	F	3	area of polygon, 0 for points
PERIMETER	4	12	F	3	perimeter length in m, 0 for points
For lines (.AAT)					
FNODE#	4	5	B	-	from node ID number
TNODE#	4	5	B	-	to node ID number
LPOLY#	4	5	B	-	left polygon ID number
RPOLY#	4	5	B	-	right polygon ID number
LENGTH	4	5	B	-	length of line in m
For points, polygons, and lines in sf-effects					
[COVNAME]#	4	5	B	-	control number assigned by ARC/INFO
[COVNAME]-ID	4	5	B	-	unique integer that identifies map element in the database (user assigned)
STA	5	5	C	-	field station number from source
EQK	10	10	C	-	date of earthquake(s)
SRC	30	30	C	-	source of information
KIND	12	12	C	-	kind of locality (point, line, area)
ACC	5	5	C	-	accuracy of location
EXT	10	10	C	-	extent of occurrence
COMM	50	50	C	-	comment by digital compiler
FIELD	50	50	C	-	field description
LS-H	1	1	I	-	landslide, hillside
LS-S	1	1	I	-	landslide, stream bank
LATSP	1	1	I	-	lateral spread
SETL	1	1	I	-	ground settlement
CRK-ST	1	1	I	-	cracks in street
CRK-GND	1	1	I	-	cracks in ground without other effect
PIPE	1	1	I	-	pipeline break
BOIL	1	1	I	-	sand boil
WELL	1	1	I	-	disturbed well
MISC	1	1	I	-	miscellaneous effect
ABS	1	1	I	-	absence of ground failure
EFFECTS	35	35	C	-	list of effects present (item names)
For all feature types					
SF	1	1	I	-	1 for inset, otherwise 0

Table 12. Description of Topical Database Fields in Ground Effects Database.

STA - The original location or field station number assigned by Youd and Hoose (1978) or Tinsley and others (1998) is recorded in the STA field. Note that for the historic data, multiple locations may have the same station number and that overlapping sequences of station numbers were used for the historic and the Loma Prieta localities.

EQK - The earthquake(s) by year of occurrence (1838-1989) for which effects are represented at each locality is reported in the EQK field.

SRC - The documentary source, either Youd and Hoose (1978), or Tinsley and others (1998), is recorded in the SRC field.

KIND - The shape or kind of occurrence is recorded in the KIND field as point, symbol, line, or area. A value of 'symbol' marks the 10 Loma Prieta localities for which only an effects symbol is shown (without an associated dot marking the mapped location). This less specific location is also indicated by an accuracy rating of Q, rather than the more accurate P.

ACC - The map accuracy of the map elements arises both from the original mapping or map placement of the effect and from digital representation of that map location. Accuracy of the historic data is recorded in the ACC field according to both the Youd and Hoose categorization (table 1) and the relocation categories of table 2. These two different accuracy categorizations are reported in that order, separated by a colon. Thus, typical ACC values might be 'A:P' or 'B,C:Q'. Quality of location accuracy on the source maps for the Loma Prieta data is also described according to the relocation categories of table 2.

EXT - The extent field is used to record dimensions for those few historic localities where the horizontal extent of the effect could be estimated. Values are in meters.

COMM – Various limiting or clarifying comments about the locality or its map location are recorded in the COMM field.

FIELD – The field occurrence of the effects is summarized for the Loma Prieta data in the FIELD field.

EFFECTS – the aggregate or combination of effects at each station is recorded in the EFFECTS field, with presence of each indicated by the field name for that effect. Typical values might thus be 'BOIL' for stations exhibiting just sand boils, or 'LATSP SETL BOIL' for stations exhibiting a combination of lateral spread, settlement, and sand boils.

The text annotation layer sf-eanno contains the station numbers, leaders, and inset box boundary used to label the ground-effects localities on map sheet 2, Liquefaction Susceptibility. All lines are leaders, with LTYPE = 'leader', except the boundary of the inset box (LTYPE = 'box') around San Francisco. Station numbers are divided into four groups that distinguish historic from Loma Prieta stations and those numbers displayed at a scale of 1:275,000 from those displayed at 1:100,000.

Loma Prieta station labels have $symbol = 21 and are level 1 (most stations) or level 3 (inset map), whereas historic labels have $symbol = 22 and are level 2 (most stations) or level 4 (inset map). Most labels are 698.5 m (map units) high for display at a scale of 1:275,000, whereas those within the inset box are 254 m high.

Points, lines, and polygons in the data layers are coded for display at a scale of 1:275,000 or on the inset map at 1:100,000. Features within the inset box have an SF value of 1, whereas all others have a value of 0.

Quadrangle Index Layer

The quadrangle index layer delineates and names the 7.5-minute quadrangles in the region. It contains attributed lines and polygons and requires polygon topology for effective use. The line attribute table (SF-QDGRID.AAT, table 13) contains the topical field LTYPE, the four different values of which are described in table 14, and the field TICS, the three values of which are described in table 15. The LTYPE field permits separate selection of the boundaries of the 7.5-minute, 15-minute, and 0.5x1.0-degree quadrangles. The TICS field permits selection of short (500 m) line segments representing the corner tics of the 7.5-minute and 15-minute quadrangles. Both are character fields. Three sets of text annotation are also included. The names of the 7.5 minute quadrangles are represented by text running diagonally across each quadrangle (level 2) and by horizontal text in the upper left corner of each quadrangle (level 3), and compilation codes (COMPIL values) are represented near the south boundary of each quadrangle (level 1). The meanings of these codes are described in table 3 of part 3, Description of Mapping.

Table 13. Structure of the Quadrangle-Index Arc Attribute Table (SF-QDGRID.AAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	
FNODE#	4	5	B	-	starting node of arc (from node)
TNODE#	4	5	B	-	ending node of arc (to node)
LPOLY#	4	5	B	-	polygon to the left of the arc
RPOLY#	4	5	B	-	polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
SF-QDGRID#	4	5	B	-	unique internal control number
SF-QDGRID-ID	4	5	B	-	unique identification number
LTYPE	35	35	C	-	type of quadrangle boundary
TICS	4	4	C	-	type of quadrangle boundary

Table 14. Quadrangle-Boundary Line Types Recorded in the Quadrangle-Index LTYPE field (SF-QDGRID.AAT)

LTYPE	
100	boundary of 0.5x1.0-degree quadrangle
15	boundary of 15-minute quadrangle (and not a 0.5x1.0-degree boundary)
7.5	boundary of 7.5-minute quadrangle (and not a 15-minute boundary)
santa cruz	boundary of the non-standard Santa Cruz 1:24,000 quadrangle

Table 15. Quadrangle Corner-Tic Line Types Recorded in the Quadrangle-Index TICS field (SF-QDGRID.AAT)

TICS	
	no value for lines that are not tics
15	corner of 15-minute quadrangle
7.5	corner of 7.5-minute quadrangle (and not a 15-minute corner)

The quadrangle-index polygon attribute table (QDGRID.PAT) contains four topical fields that are described in table 16. The NAME and SHEET fields identify the 7.5-minute quadrangle and the 0.5x1.0-degree quadrangle that contains it. The COMPIL field contains the map compilation code described in part 3, Description of Mapping, and the PERCENT field contains the percent completion of Quaternary mapping for each 7.5-minute quadrangle according to the criteria described in part 3 (values range from 50 to 100, in 5 percent increments). The 7.5-minute quadrangles in the index map on map sheet 1 (Quaternary Deposits) are colored according the PERCENT values, and the COMPIL codes are posted in the lower left corner of each quadrangle. COMPIL values containing 6, 10, or 11 represent largely 1:100,000-scale material, whereas the others represent 1:24,000-scale materials.

Table 16. Structure of the Quadrangle-Index Polygon Attribute Table (SJ-GEOL.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
SF- QDGRID #	4	5	B	-	unique internal control number
SF- QDGRID –ID	4	5	B	-	unique identification number
NAME	35	35	C	-	name of 7.5-minute quadrangle
SHEET	35	35	C	-	name of 0.5x1.0-degree quadrangle
COMPIL	7	7	C	-	compilation code
PERCENT	3	3	I	-	percent completion of mapping
SCALE	4	4	I	-	scale of source map (24 or 100)

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