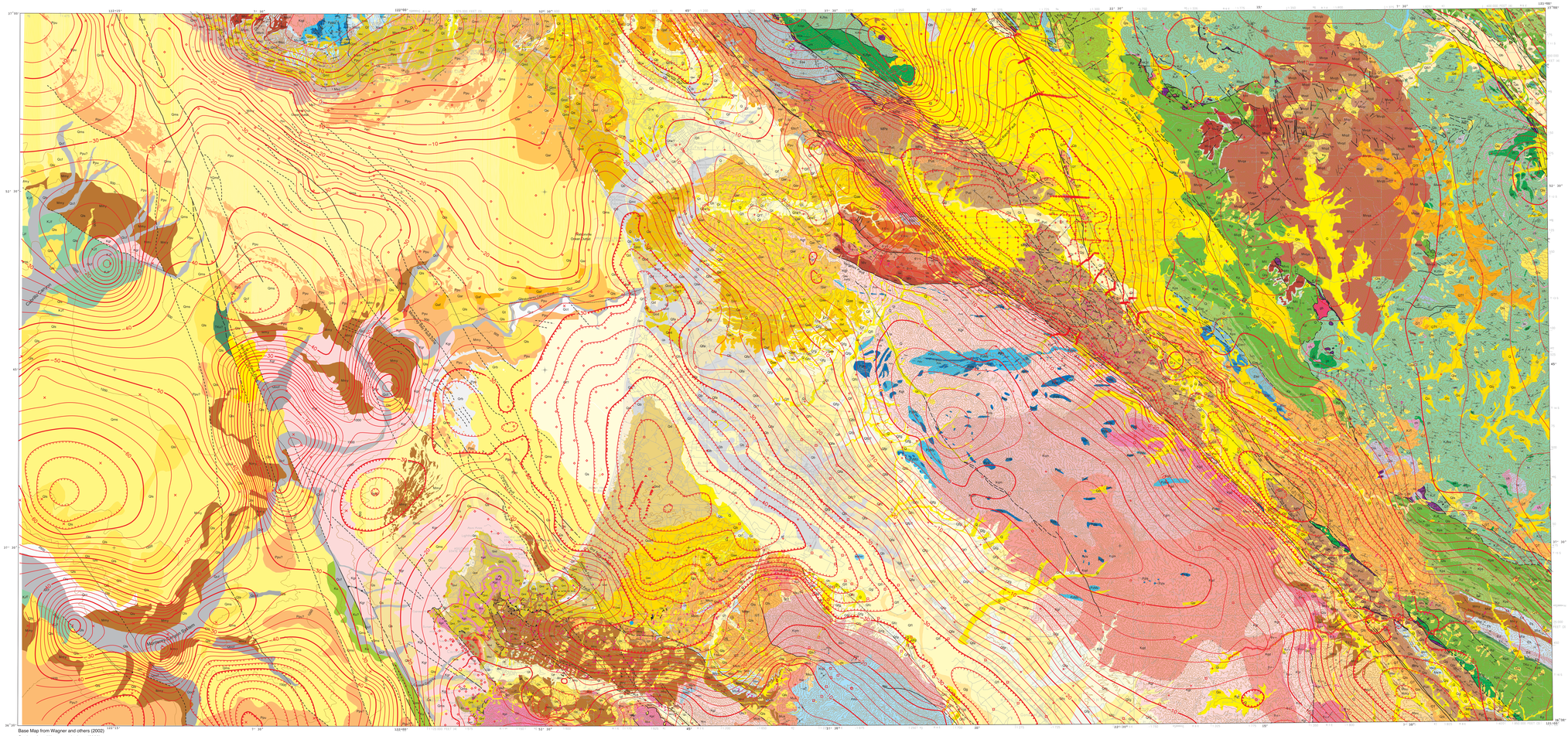
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 02-373



Base Map from Wagner and others (2002)
Geology from Wagner and others (2002)
Note label leaders and contacts have been removed.

SCALE 1:100,000

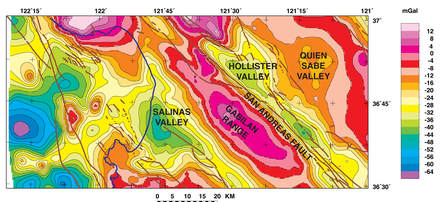
6 Miles

6 Kilometers

ISOSTATIC GRAVITY MAP OF THE MONTEREY 30'x60' QUADRANGLE AND ADJACENT AREAS, CALIFORNIA

V.E. Langenheim, S.R. Stiles, and R.C. Jachens
2002

COLOR ISOSTATIC GRAVITY MAP



INDEX MAP

GRAVITY EXPLANATION

Gravity anomaly contours. Contour interval, 2 mGal. Hachures indicate gravity low. Contours were computer-generated based on a 300-m grid. Although the data have been edited, caution should be exercised when interpreting anomalies controlled by only a single gravity station.

STATION LOCATIONS

- National Geophysical Data Center
- Underwood thesis
- Shiptrack
- Ocean-bottom gravity (Navy)
- Previously published (Roberts et al., 1990)
- U.S. Geological Survey 1990-2000

LIST OF MAP UNITS

Holocene

- Q — Alluvium
- d — Artificial fill
- Qe — Eolian sand
- Qo — Older alluvium
- Qt — Terrace deposits
- Qm — Marine terrace deposits
- Qf — Alluvial fan deposits
- Qfa — Fan deposits of Antioch
- Qfc — Fan deposits of Chular
- Qfp — Fan deposits of Placentia
- Qfg — Fan deposits of Gloria
- Qsr — Aromas Sand (undivided)
- Qse — Eolian facies
- Qsf — Fluvial facies
- Qg — Stream gravel
- Qs — Sand
- Qd — Dune sand
- Qls — Landslide deposits
- Qdd — Older Dune Sand
- Qhw — Terrace deposits of Watsonville terrace
- Qfl — Flood plain deposits
- Qcf — Canyon Fill (offshore)
- Qms — Marine sediments
- Qocf — Older canyon fill (offshore)
- Qrb — Relict beach deposits (offshore)
- Qct — Submarine canyon terrace
- Qb — Basin deposits
- Qp — Patterson Alluvium
- Qsl — San Luis Alluvium
- Qlb — Los Banos Alluvium

Pleistocene

- Qtc — Plio-Pleistocene continental deposits
- Qtf — Plio-Pleistocene fluvial deposits
- Qtl — Plio-Pleistocene lacustrine deposits

Pliocene

- Pcc — Unnamed Pliocene continental mudstone
- Pcs — Unnamed Pliocene Continental sandstone
- Ppu — Purisima Formation
- Ppr — Pancho Rico Formation
- Pb — Pliocene Basaltic rocks (Coyote Volcanics)

Miocene

- Mtf — Etchegoin Formation
- Msc — Santa Cruz Mudstone
- Mu — Unnamed Miocene volcanic rocks
- Mzq — QUIEN SABE VOLCANICS: Mzqp - Andesitic flows and breccia; Mzqb - Basaltic flows and breccia; Mzqd - Dacite flows; Mzqr - Rhyolite flows; Mzqt - Intrusive andesite; Mzqb - Intrusive basalt; Mzqd - Intrusive dacite; Mzqr - Intrusive rhyolitic rocks
- Tv — Tertiary volcanic rocks: Tva - Andesite; Tvb - Basalt
- Msr — Santa Margarita Sandstone
- Mzu — Unnamed Miocene sedimentary rocks
- Mmr — Monterey Formation
- Mm — Organic mudstone
- Lompico Sandstone
- Mbt — Temblor (Mv-Basalt interbed)
- Mzs — Unnamed Miocene sandstone
- Mlt — Lone Tree Fm.

Oligocene

- Orb — Red beds
- Ovq — Vaqueros Sandstone
- Opi — Pinnacles volcanic formation
- Osj — San Juan Bautista Formation
- Oca — Carmelo of Lawson
- Ezu — Unnamed Eocene sedimentary rocks

Paleocene-Eocene

- Ec — Carmelo Formation
- Elm — Los Muertos Formation
- Ek — Kreyenhagen Formation
- Tpn — Tres Pinos Sandstone
- Ed — Domengine Sandstone
- Ess — Arkosic sandstone
- Ec — Cartua Sandstone
- Pzc — Paleocene-Eocene sedimentary rock

Cretaceous

- Tzu — Tertiary-Cretaceous sedimentary rock
- Kzu — Upper Cretaceous sedimentary rocks
- Kp — Panoche Formation: Kps - Sandstone; Kpc - Conglomerate
- Kgr — Granitic rocks
- Kqm — Quartz monzonite
- Kqd — Quartz diorite
- Kgd — Granodiorite
- Kf — Franciscan Complex*
- Kg — Conglomerate
- Ks — Sandstone
- Ch — Chert
- Kzu — Jurassic-Cretaceous sedimentary rocks

Jurassic

- Gr — Greenstone
- Sp — Serpentinite ultramafic rock
- Sz — Blueschist and semischist
- L — Limestone
- Gb — Gabbro
- Ggq — Gabbro of Logan quarry
- Pzpu — Paleozoic-Proterozoic sedimentary rocks Pzls - Carbonate rocks

*part of KJf is melange (KJfm)

Coast Range Ophiolite

- Jbr — Breccia
- Jv — Volcanic rocks (greenstone)
- Js — Serpentinized ultramafic rock

- Jmsc — Schist of Sierra de Salinas

SYMBOLS

Fault–solid where certainly located; dashed where approximately located or inferred; dotted where concealed; queried where existence or continuation is uncertain. Arrows show direction of dip where known.

Thrust fault–barbs on upper plate; solid where certainly located; dased where approximately located or inferred; dashed where concealed; queried where existence or continuation uncertain. Arrow indicates direction of dip when known.

Anticlinal fold–solid where certainly located; dashed where inferred; dotted where concealed, queried where existance or continuation is uncertain.

Synclinal fold–solid where certainly located; dashed where inferred; dotted where concealed, queried where existance or continuation is uncertain.

80 — Strike and dip of stratified rocks–Number indicates dip angle in degrees when known.

Vertical beds

60 — Overturned beds

Horizontal beds

25 — Strike and dip of foliations

Arrows on landslides indicate direction of movement.

Introduction

This isostatic residual gravity map is part of a 3-dimensional mapping project and is intended to promote further understanding of the geology in the Monterey 1:100,000-scale quadrangle, California, by serving as a basis for geophysical interpretations and by supporting both geological mapping and topical studies. Local spatial variations in the Earth's gravity field (after various corrections for elevation, terrain, and deep crustal structure explained below) reflect the distribution of densities in the mid- to upper crust. Densities often can be related to rock type, and abrupt spatial changes in density commonly mark lithologic boundaries.

High-density basement rocks exposed within the Monterey quadrangle generally include metamorphic rocks and Mesozoic plutonic rocks present in the mountainous areas of the quadrangle. Plutonic bodies of mafic composition, such as gabbro or diorite, are usually responsible for gravity highs whereas felsic plutons (and Cretaceous sedimentary rocks) where juxtaposed against denser metamorphic or igneous rocks commonly cause local gravity lows. Alluvial sediments, usually located in the valleys, and Tertiary sedimentary rocks are characterized by low densities. However, with increasing depth of burial and age, the densities of these rocks may become indistinguishable from those of basement rocks. Plotting gravity contours directly on a geologic base facilitates identification of geologically feasible sources of the anomalies.

Isostatic residual gravity values within the Monterey quadrangle range from about -60 mGal over the offshore sedimentary basins (western part of map) to about 14 mGal in the Santa Cruz Mountains in the northwestern part of the map. A steep linear gravity gradient is coincident with the trace of the San Andreas Fault along much of its length in the Monterey 1:100,000-scale quadrangle. The contact between granitic rocks of the Gabilan Range and Cenozoic sedimentary rocks is located near the base of a very linear, 25-mGal gravity gradient, indicating that low-density sediments are underthrust beneath the Gabilan Range along this stretch of the San Andreas fault (Pavoni, 1973).

Data Sources, Reductions, and accuracies

Gravity data in the Monterey 1:100,000-scale quadrangle and vicinity include 1780 gravity stations compiled by Roberts and others (1990), 57 gravity stations from the National Geophysical Data Center (written commun., 1999), 38 stations from Deborah Underwood (University of Santa Cruz, written commun., 1998), 202 ocean-bottom gravity stations, 88 values from shiptrack data, and 142 U.S. Geological Survey stations (post 1990). The datum of observed gravity for this map is the International Gravity Standardization Net of 1971 (IGSN 71) as described by Morelli (1974); the reference ellipsoid used is the Geodetic Reference System 1967 (GRS67; International Association of Geodesy, 1971).

The observed gravity data were reduced to free-air anomalies using standard formulas (e.g. Telford and others, 1976). Bouguer, curvature, and terrain corrections (to a distance of 166.7 km; Plouff, 1977) were applied to the free-air anomaly at each station to determine the complete Bouguer anomalies at a standard reduction density of 2.67 g/cm^3. An isostatic correction was then applied to remove the long-wavelength effect of deep crustal and/or upper mantle masses that isostatically support regional topography. The isostatic correction assumes an Airy-Heiskanen model (Heiskanen and Vening-Meinesz, 1958) of isostatic compensation; compensation is achieved by varying the depth of the model crust-mantle interface, using the following parameters: a sea-level crustal thickness of 25 km, a crust-mantle density contrast of 0.40 g/cm^3, and a crustal density of 2.67 g/cm^3 for the topographic load. These parameters were used because (1) they produce a model-crustal geometry that agrees with seismically determined values of crustal thickness for central California, (2) they are consistent with model parameters used for isostatic corrections computed for the rest of California (Roberts and others, 1990), and (3) changing the model parameters does not significantly affect the resulting isostatic anomaly (Jachens and Griscom, 1985). The computer program ISOCOMP (Jachens and Roberts, 1981) directly calculates the attraction of an Airy-Heiskanen root by summing the attraction of individual mass prisms making up the root and thus calculating the isostatic correction; the resulting isostatic residual gravity values should reflect lateral variations of density within the mid- to upper crust.

Offshore data come from two sources. Ocean-bottom measurements reduced to complete Bouguer gravity values (Brooks, 1973; Cronyn, 1973; Soulo, 1973; Spikes, 1973; Woodson, 1973) were corrected to isostatic anomalies. Trackline points were digitized from intersections of simple Bouguer gravity anomaly contours with tracklines (Chapman and others, 1990) and then reduced to Complete Bouguer and isostatic anomalies.

The main sources of error are inaccurate elevations and/or inaccurate terrain corrections. Errors associated with terrain corrections may be 5 to 10 percent of the value of the total terrain correction. The average error based on the average terrain correction (2.07 mGal) is thus about 0.2 mGal, but in the most rugged areas of the Gabilan Range, the individual errors may be as large as 2.1 mGal. Errors resulting from elevation uncertainties are probably less than 0.5 mGal for most of the data because the majority of the stations are at or near bench marks and spot and surveyed elevations, which are accurate to about 0.2 to 3 m. Measurements for which elevations were controlled by contour interpolation are expected to have errors of up to 1.2 mGal. In general, the total uncertainties for the onshore and ocean-bottom data shown on the map are estimated to be less than 2 mGal (or one contour interval), although in many areas the data are considerably more accurate. The shiptrack data are considerably less accurate, with errors in the gravity measurement alone as high as 3 mGal (Oliver and others, 1980, p. 4)

References

Brooks, R.A., 1973, A bottom gravity survey of the shallow water regions of southern Monterey Bay and its geological interpretation: Naval Postgraduate School Master's thesis, 90 p.

Chapman, R.H., Chase, G.W., and Youngs, L.G., 1990, Bouguer gravity and magnetic anomaly map of the central California continental margin: California Continental Margin Geologic Map Series Central California Continental Margin Map no. 5C, scale 1:250,000.

Cronyn, B.S.,in 1973, Underwater gravity survey of northern Monterey bay: Naval Postgraduate School Master's thesis, 53 p.

Heiskanen, W.A., and Vening-Meinesz, F.A., 1958, The Earth and its gravity field: New York, McGraw-Hill Book Company, Inc., 470 p.

International Union of Geodesy and Geophysics, 1971, Geodetic reference system 1967: International Association of Geodesy Special Publication no. 3, 116 p.

Jachens, R.C., and Griscom, A, 1985, An isostatic residual gravity map of California—a preliminary interpretation emphasizing gravity anomalies caused by Tertiary extension in Hope, W.J., ed., The Utility of Regional Gravity and Magnetic Anomaly Maps: Society of Exploration Geophysicists, Tulsa, Okla.,p. 347-360.

Jachens, R.C., and Roberts, C.W., 1981, Documentation of a Fortran program, ISOCOMP, for computing isostatic residual gravity: U.S. Geological Survey Open-File Report 81-574, 26 p.

Morelli, Carlo, (ed.), 1974, The International gravity standardization net 1971: International Association of Geodesy Special Publication no. 4, 194 p.

Oliver, H.W., 1980, Interpretation of the gravity map of California and its continental margin: California Division of Mines and Geology Bulletin 205, 52 p.

Pavoni, Nazario, 1973, A structural model for the San Andreas fault zone along the northeast side of the Gabilan Range in Kisbach, R.L., and A.Nur (eds.), Proceedings of the Conference on Tectonic Problems of the San Andreas Fault System, Geological Sciences, v. 13, Stanford University,p. 259-267.

Plouff, Donald, 1977, Preliminary documentation for a FORTRAN program to compute gravity terrain corrections based on topography digitized on a geographic grid: U.S. Geological Survey Open-File Report 77-535, 45 p.

Roberts, C.W., Jachens, R.C., and Oliver, H.W., 1990, Isostatic residual gravity map of California and offshore southern California: California Division of Mines and Geology, Geologic Data Map No. 7, scale 1:750,000.

Soulo, A.P.D, 1973, A bottom gravity survey of Carmel Bay, California: Naval Postgraduate School Master's thesis, 68 p.

Spikes, C.H., 1973, A gravimetric survey of the Santa Cruz-Ano Nuevo Point continental shelf and adjacent coastline: Naval Postgraduate School Master's thesis, 114 p.

Telford, W.M., Geldart, L.O., Sheriff, R.E., and Keyes, D.A., 1976, Applied Geophysics: New York, Cambridge University Press, 860 p.

Wagner, D.L., Greene, H.G., Saucedo, G.J., and Pridmore, C.L., 2002, Geologic map of the Monterey 30' x 60' quadrangle and adjacent areas, California: A Digital database: California Geological Survey CD 2002-04.

Woodson, W.B., 1973, A bottom gravity survey of the continental shelf between Point Lobos and Point Sur, California: Naval Postgraduate School Master's thesis, 110 p.

This report 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.