GEODESY LESSON PLAN

It's Not Your Fault

Focus

Tectonic Plate Movement

Grade Level

9-12

Focus Question

How can we measure the relative motions of the Pacific Plate and the North American Plate along the San Andreas Fault?

Learning Objectives

- Students will be able to compare and contrast movements on either side of the San Andreas Fault.
- Students will be able to calculate the amount of movement of a tectonic plate over a period of time.
- Students will be able to describe the processes involved in the occurrence of earthquakes along the San Andreas Fault.

Materials

- Computer with internet access and a working email account (if computer access is not available, you may use the data sets included in "Tracking Plate Movement – Answers")
- Copies of "Using CORS Data", one for each student or student group
- Copy of "Using CORS Data – Teacher's Guide" for teacher's reference
- Copies of "Student Sheet Tracking Plate Movement Along the San Andreas Fault", one for each student or student group.
- Calculator or spreadsheet program, such as Microsoft Excel.
- Metric ruler, one for each student or student group.
- Copies of either "Geodesy Review" (fill-in-the-blank version, with or without word bank) or Geodesy Review Crossword Puzzle, one copy for each student or student group

Audio/Visual Materials

None

Teaching Time

Three 45-minute class periods, plus one additional class period to complete the "Meet Geodesy" lesson, if desired

Seating Arrangement

Groups of four students

Maximum Number of Students

This depends upon the availability of computers; if access is limited you might have one group retrieving data while the remaining groups complete one version of the "Geodesy Review". If students are divided into groups of four, you may have each person in the group retrieve and analyze a different data set.

Key Words

GPS
CORS
OPUS
San Andreas Fault
Transform plate boundary

Background

[NOTE: See the "Meet Geodesy" lesson plan for background on the science and importance of geodesy.]

The National Geodetic Survey (NGS) uses Global Positioning System (GPS) data to measure 3-dimensional positions on the Earth's surface with accuracies of 1 centimeter or better. These measurements enable the detection of subtle displacements of the Earth's crust due to seismic events over relatively short periods.

Hundreds of permanent and continuously tracking GPS stations have been installed throughout the United States and practically all of the data produced by these stations are available through the Internet. NGS provides much of these data through its Continuously Operating Reference Station (CORS) Network. NGS has also initiated its On-line Positioning User

Service (OPUS) where GPS data are submitted through the OPUS Web site, the data are processed and the results e-mailed back to the user within a matter of minutes. The precision of these OPUS results, the density of the GPS tracking networks, the simplicity of the data processing, and the on-line data archive (reaching back in many cases over 5 years) allow analysis of crustal motions in all 50 states.

The CORS Network in California allows for the detection of movements along the San Andreas Fault. The San Andreas Fault is a transform plate boundary; this is an area where two tectonic plates are sliding past each other. The fault is approximately 1,300 km (800 miles) long and cuts through about two-thirds the length of California. Along the fault, the Pacific Plate is moving northwest past the North American plate at a rate of several centimeters per year.

Movement along the length of the fault occurs at different rates. In some sections, the land on either side of the fault seems to be in constant motion as the plates slide past each other. In other areas, the plates are moving past each other at different rates, which causes geological stress to build up as the plates try to push past each other. This stress can result in fairly significant earthquakes. Finally, in other areas where the forces are trying to push the plates, but the plates get "locked", or do not move. This allows the stresses to build over time; the earthquakes that result from these situations are the ones that tend to be the most devastating.

In this lesson, students will analyze geodetic data from sites near the San Andreas Fault, and calculate the movement of the tectonic plates that border this fault.

Learning Procedure

[NOTE: You may want to complete part or all of the "Meet Geodesy" lesson plan if students have not been previously introduced to this science.]

1. Briefly introduce the concept of measuring displacements in the Earth's crust using geodetic data, and describe the overall structure and location of the San Andreas Fault and the adjoining tectonic plates.

2.

Have students review the packet called "Using CORS Data". Go over this with students ahead of time so they are familiar with how to retrieve the needed information from the NGS-CORS Web site (*http://www.ngs.noaa.gov/CORS/download2*).

3.

Student will need the following RINEX2 files from the NGS-CORS Web site. Have each student or student group get data for one or more of the dates listed for the following sites:

DHLG (Durmid Hill, CA)

Dates:

- January 1, 2000
- July 1, 2000
- January 1, 2001
- July 4, 2001
- January 9, 2002
- July 1, 2003

MHCB (Mount Hamilton, CA)

Dates:

- January 1, 2000
- July 1, 2000
- January 1, 2001
- July 4, 2001
- January 1, 2002
- July 1, 2003

MONP (Monument Peak, CA)

Dates:

- January 1, 2000
- July 1, 2000
- January 1, 2001
- July 4, 2001
- January 1, 2002
- July 1, 2003

PPT1 (Pigeon Point, CA)

Dates:

- January 1, 2000
- July 1, 2000
- January 1, 2001

July 4, 2001
January 1, 2002
July 1, 2003

4.
Submit the files to OPUS. Use the following information for antennas:

DHLG: ASH701945B_M D/M element, REV. B, chokering
MHCB: ASH700936D_M D/M element, milled chokerings, -radome
MONP: ASH701945B_M D/M element, REV. B, chokering
PPT1: AOAD/M_T Dorne Margolin T, chokerings (TurboRogue)

Use the following 3 sites as the base sites:

COSO (Coso Junction, CA)
GOL2 (Goldstone, CA)
MINS (Minaret Summit, CA)

5.
Extract the latitude and longitude elevation information from each OPUS solution.

6.
On the map provided, have students plot the original position of each of the CORS sites. They should note where their site is relative to the San Andreas Fault.

7.
Have students follow worksheet directions to calculate the changes in latitude and longitude of their CORS site.

8.
Have students share data with their group members for the change in latitude and longitude of each of the CORS sites.

9.
Have students graph the Change in Latitude vs. Date and Change in longitude vs. Date for each site on the graphs provided.

10.
On the map, using a scale of 1 cm = 1 mm, have students draw in the movement of their CORS site over time in the north/south and east/west direction.

11.
Have students answer the questions on the worksheet.

12.
Lead a discussion of the student's results using answers in the file "Tracking Plate Movement – Answers" as a guide. Students should recognize that Monument Peak and Pigeon Point are located to the west of the San Andreas Fault on the Pacific plate, while Mount Hamilton and Durmid Hill are located to the east of the Fault on the North American plate. Monument Peak and Pigeon Point usually experienced larger displacements than the other two sites on the dates studied, suggesting more active movement of the underlying tectonic plates. You may want to show a map of the area as you discuss how the latitude and longitude change data can indicate the direction of plate motion. Students should infer that increasing latitude indicates a northerly motion (in the northern hemisphere), while increasing longitude indicates a westerly motion (in the western hemisphere). Since sites on the Pacific plate exhibited increasing latitude and longitude, students should infer that this plate has a northwesterly direction of motion. Similarly, since sites on the North American plate exhibited decreasing latitude and increasing longitude, they should infer that this plate has a southwesterly direction of motion.

The Bridge Connection

www.vims.edu/bridge/ Click on "Search" in the box on the upper right and enter: "earthquake."

The "Me" Connection

The San Andreas Fault is near many large population centers. Have students write a short essay explaining how much importance they would attach to earthquake probability when deciding on a place to live.

Connections to Other Subjects

Geography, Technology, and Mathematics

Evaluation

The teacher will review the student's "Tracking Plate Movement Along the San Andreas Fault" worksheet.

Extensions

1. Visit *http://geodesy.noaa.gov/TOOLS/* to learn more about the kinds of information that can be obtained through geodesy.

2. Have students visit *http://geodesy.noaa.gov/INFO/NGShistory.html* and prepare a brief report highlighting advances in geodesy since the establishment of the National Geodetic Survey in 1807.

3. Visit *http://mceer.buffalo.edu/education/exercises/struct.asp* to learn about designing structures to perform well during an earthquake.

4. Visit *http://www.exploratorium.edu/faultline/activities/index.html* for ideas from the exploratorium to learn more about earthquakes.

Resources

http://www.ngs.noaa.gov/CORS/ – Web site for the National Geodetic Survey's network of continuously operating reference stations (CORS) that provide Global Positioning System (GPS) measurements to support accurate determination of locations and elevations throughout the United States and its territories.

http://www.ngs.noaa.gov/OPUS – Web site for the National Geodetic Survey's On-line Positioning User Service (OPUS). This service allows users to submit GPS data files to NGS, where the data are processed to determine a position using NGS computers and software. Calculated positions are reported back via email.

http://geodesy.noaa.gov/PUBS_LIB/thePossibilities/Imagine.html – A brochure (in pdf format) explaining the role of geodesy in contemporary America.

http://oceanservice.noaa.gov/news/features/supp_sep03.html – National Ocean Service Web site that describes the National Spatial

Reference System, Global Positioning System, and why geodesy is important.

http://geodesy.noaa.gov/GEOID/ – The National Geodetic Survey's Web site with definitions, descriptions, and links to research and information about the geoid, including a slide show on gravity and the geoid

http://geodesy.noaa.gov/GRD/ – Web site of the Geosciences Research Division of the National Geodetic Survey, with current projects, data, software and archives

http://geodesy.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003A.HTM – A "classic" report which presents the basic principles of geodesy in an elementary form.

http://einstein.gge.unb.ca/tutorial/tutorial.htm – An introduction to geodesy by the Geodesy Group at the University of New Brunswick.

http://geodesy.noaa.gov/faq.shtml – Frequently Asked Questions about geodesy and the National Geodetic Survey

http://geodesy.noaa.gov/INFO/NGShistory.html – History of the National Geodetic Survey, which was the first civilian scientific agency in the United States, established by President Thomas Jefferson in 1807

http://geodesy.noaa.gov/geodetic_links.shtml – links to other organizations, information, and resources about geodesy

http://bowie.gsfc.nasa.gov/926/ – Web site of the Space Geodesy Branch of the Laboratory for Terrestrial Physics located at NASA's Goddard Space Flight Center; visit *http://denali.gsfc.nasa.gov/dtam/* for maps of tectonic activity, seismicity, and volcanism, and *http://cddisa.gsfc.nasa.gov/926/noamtect.html* for a map of tectonic motion in North America

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard D: Earth and Space Science
- Energy in the earth system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

GEODESY LESSON PLAN

Using CORS Data

Introduction

The National Geodetic Survey (NGS) uses GPS data to measure 3-dimensional positions on Earth's surface with precisions of 1 centimeter or better. These precise measurements enable the detection of subtle displacements due to tectonic motion and subsidence over relatively short time periods.

Hundreds of permanent and continuously tracking GPS stations have been installed throughout the United States and practically all these data are available through the World Wide Web. NGS provides much of these data through its Continuously Operating Reference Station (CORS) Network. NGS has also initiated its On-line Positioning User Service (OPUS), whereby GPS data is submitted through NGS' Web site, the data is processed and the results emailed back to the user within a matter of minutes. The precision of these OPUS results, the density of the GPS tracking networks, the simplicity of the data processing, and the on-line data archive (reaching back in many cases over 5 years) allow analysis of crustal motions in all 50 states.

Several exercises have been developed, which will enable students to use these data to illustrate contemporary tectonic movement, subsidence, and post-seismic displacement. NGS believes these GPS data provide an invaluable resource to illustrate natural and manmade dynamic processes of the earth's surface.

Step 1: Getting the RINEX2 data.

In this step you will download RINEX2 (Receiver Independent Exchange) files to your computer for a particular site and particular dates.

Go to the NGS CORS download page: *http://www.ngs.noaa.gov/CORS/download2*.

Get RINEX2 files for one of the sites. You will need to make a separate request for each day and each site.

You will need to save the RINEX2 files to your computer. There is a specific format to the file names. Save the files that have an "o" after the year. You will have one file for each day. File-naming scheme:

① ② ③ ④ ⑤

tlka0010.03o.gz

① 4 letter site ID

② day of the year (For example,
0010 = day 1 or Jan 1st;
3650 = day 365 or Dec 31st)

③ year

④ file type (This part of the file name may vary. You always want to save the files that have an"o" here.)

⑤ indicates the file is zipped (compressed)

Step 2: Submitting the data to OPUS.

Once you have saved the files, you are ready for the next step. This is to submit the data to OPUS (On-line Positioning User Service). OPUS will determine the latitude, longitude, and elevation of the site for each day and then email the results back to you.

Go to the OPUS page: *http://www.ngs.noaa.gov/OPUS/*

Enter the following information:
An email address to which OPUS can send your files.

The location of the RINEX2 files you saved from the previous step.

Antenna data. This will vary for each site, and is specified for each exercise.

Leave as "0.0 m".

Leave as "0 NONE" for state plane coordinates.

Click "OPTIONAL – PICK/REMOVE SITES". Once you are there, you will need to choose the 3 sites to be used as base sites. This will vary and is specified for each exercise.

Click "upload file". An OPUS solution file will be emailed to you for that particular day. Click the back button on your browser and repeat the process for the additional days.

Step 3. Getting the desired information from the OPUS email.

You will receive a separate email for each day and site you have submitted to OPUS. There is a lot of information in the email that you will NOT need to use. A sample email is attached, and the information that you will need is circled. This will consist of a latitude, longitude (expressed as east and west), and an elevation. The precision of these coordinates are to the hundred thousandths of a second. This ***is*** significant, as it will translate to changes on the order of centimeters.

Sample OPUS email:

```
From: <opus@ngs.noaa.gov>
To: <nobody@capital.net>
Subject: OPUS solution : fair2990.02o
Date: Mon, 7 Jul 2003 14:11:28 -0400 (EDT)
FILE: fair2990.02o

1008 WARNING! Antenna offsets supplied by the user in the RINEX
1008 header or via the web were zero. Coordinates returned will
1008 be for the antenna reference point (ARP). Please refer to
1008 the following web address for an example.
1008 http://www.ngs.noaa.gov/CORS/OPUS/Preprinfile.html
1008
NGS OPUS SOLUTION REPORT
========================

USER: meghanlm\@capital.net DATE: July 07, 2003
RINEX FILE: fair2990.02o TIME: 18:11:18 UTC


SOFTWARE: page5 0203.19 ./master.pl START: 2002/10/26 00:00:00
EPHEMERIS: igs11896.eph [precise] STOP: 2002/10/26 23:59:00
NAV FILE: brdc2990.02n OBS USED: 37163 / 45755 : 81%
ANT NAME: AOAD/M_T # FIXED AMB: 260 / 380 : 68%
ARP HEIGHT: 0.0 OVERALL RMS: 0.022(m)


REF FRAME: NAD83(CORS96)(EPOCH:2002.0000) ITRF00 (EPOCH:2002.8178)
X: -2281620.804(m) 0.022(m)       -2281621.598(m) 0.028(m)
Y: -1453596.866(m) 0.019(m)       -1453595.833(m) 0.018(m)
Z: 5756961.509(m) 0.041(m)              5756961.920(m) 0.067(m)
```

These are the data to use.

```
LAT: 64 58 40.79751 0.021(m)       64 58 40.79977 0.010(m)
E LON: 212 30 2.83614 0.010(m)     212 30 2.73719 0.002(m)
W LON: 147 29 57.16386 0.010(m)    147 29 57.26281 0.002(m)
EL HGT: 318.646(m) 0.041(m)        319.067(m) 0.074(m)
ORTHO HGT: 307.494(m) 0.048(m)  [Geoid99 NAVD88]

UTM: Zone 6
NORTHING: 7206095.659(m)
EASTING: 476439.652(m)

US NATIONAL GRID DESIGNATOR: 6WVT7644006096(NAD 83)

BASE STATIONS USED
PID DESIGNATION LATITUDE LONGITUDE DISTANCE(m)
AF9547 BAY1 COLD BAY 1 CORS ARP N551124.982 W1624225.700 1370317.3
AJ8056 PBOC PRUDHOE BAY 2 CORS ARP N701523.051 W1482005.563
589563.0
AF9530 AIS1 ANNETTE ISLAND 1 CORS ARP N550408.647 W1313558.255
1404793.4

NEAREST NGS PUBLISHED CONTROL POINT
AF9535 GILMORE CREEK CORS MONUMENT N645840.795 W1472957.160 0.0

This position was computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating
procedures used.
```

GEODESY LESSON PLAN

Using CORS Data – Teacher's Guide

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Step 2: Submitting the data to OPUS.

Once you have saved the files, you are ready for the next step. This is to submit the data to OPUS (On-line Positioning User Service). OPUS will determine the latitude, longitude, and elevation of the site for each day and then email the results back to you.

Go to the OPUS page: *http://www.ngs.noaa.gov/OPUS/*

Enter the following information:
An email address to which OPUS can send your files.

The location of the RINEX2 files you saved from the previous step.

Antenna data. This will vary for each site, and is specified for each exercise.

Teacher's Note:

There are several different antennas that may be used at a CORS location. The antenna information for a particular site can be accessed from the CORS Download page by getting the "Coordinates" file for a particular site. It is located about halfway down on the page.

Leave as "0.0 m".

Leave as "0 NONE" for state plane coordinates.

Click "OPTIONAL – PICK/REMOVE SITES". Once you are there, you will need to choose the 3 sites to be used as base sites. This will vary and is specified for each exercise.

Teacher's Note:

These base stations have been carefully selected based on location and data availability

Click "upload file". An OPUS solution file will be emailed to you for that particular day. Click the back button on your browser and repeat the process for the additional days.

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SOFTWARE: page5 0203.19 ./master.pl START: 2002/10/26 00:00:00
EPHEMERIS: igs11896.eph [precise] STOP: 2002/10/26 23:59:00
NAV FILE: brdc2990.02n OBS USED: 37163 / 45755 : 81%
ANT NAME: AOAD/M_T # FIXED AMB: 260 / 380 : 68%
ARP HEIGHT: 0.0 OVERALL RMS: 0.022(m)
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AJ8056 PBOC PRUDHOE BAY 2 CORS ARP N701523.051 W1482005.563
589563.0
AF9530 AIS1 ANNETTE ISLAND 1 CORS ARP N550408.647 W1313558.255
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NEAREST NGS PUBLISHED CONTROL POINT
AF9535 GILMORE CREEK CORS MONUMENT N645840.795 W1472957.160 0.0

This position was computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating
procedures used.
```

Step 4: Organizing the Data to See Changes.

In order to see changes in position, students will need to graph the data. This can either be done by hand or students could input their data into a spreadsheet program and create graphs from the data. Microsoft Excel works well.

The displacements that occur for these events are on the order of centimeters. Therefore, the degrees and minutes of latitude and longitude do NOT vary. For this reason, analysis of the data from this point forward will focus on the **seconds** of latitude and longitude.

Step 5: Converting Latitude & Longitude Changes into More Meaningful Units (Centimeters).

Overall, each site had movement in a horizontal and/or vertical direction. These movements are relatively small, so they are expressed in fractions of a second. The next step is to express these small numbers in units students are more familiar with: centimeters.

Note: You only need to deal with the seconds of latitude and longitude for all of the following steps.

Use a proportion and the information below to convert the change in latitude seconds into centimeters:

1 second of latitude = 3092.36 centimeters

Longitude is more complicated to deal with than latitude since longitude lines converge at the poles. A change in 1 degree of longitude at the equator would represent a much larger distance than a change of 1 degree of longitude close to the poles. Therefore, longitude values need to be calculated as a function of latitude. Use the information below to convert the change in longitude seconds into centimeters. *For this calculation, you can round the latitude to the nearest whole degree.*

1 second of longitude = 3092.36 centimeters * cos (latitude)

GEODESY LESSON PLAN

Tracking Plate Movement Along the San Andreas Fault

Name ______________________________ **Period** ______ **Date** ________

Carefully follow the directions below to fill in the Latitude & Longitude Data chart.

Column A: Fill in the date for each of the 8 days you received data for from OPUS.

Columns B and C: Fill in the latitude and longitude from the OPUS solution. See "Using CORS Data" packet.

Column D: Calculate the change in latitude over time, using January 1, 2000 as the starting point. Do this by subtracting the latitude of your site on January 1, 2000 from the latitude of your site on the date you're computing the change for. [For example, do D2 – D1, then D3 – D1, etc.]

Set your first one up here:

Latitude on 7/2000 [D2] - Latitude on 1/2000 [D1] = change in latitude

________________ - ________________ = ____________

Note: Degrees and minutes will cancel out and you will be left with fractions of a second.

Column E: Convert the change in latitude from seconds into centimeters. One second of latitude is equal to 3092.36 centimeters, so this can be done by multiplying each value in Column D by 3092.36 centimeters.

Column F: Calculate the change in longitude over time, using the same method as in Column D.

Note: Again, degrees and minutes will cancel out and you will be left with fractions of a second.

Column G: Convert the change in longitude from seconds into centimeters. Longitude is more complicated to deal with than latitude since longitude lines converge at the poles. A change in 1 degree of longitude at the equator would represent a much larger distance than a change of 1 degree of longitude close to the poles. Therefore, longitude values need to be calculated as a function of latitude. Multiply each value in Column F by 3092.36 centimeters * cos (latitude).

Note: For this calculation, you can round the latitude of your site to the nearest whole degree.

Latitude & Longitude Data

Input the information from your site into the chart below.

Site Name:

A	B	C	D	E	F	G
Date	Latitude (deg, min, sec)	Longitude (deg, min, sec)	Change in Latitude (seconds)	Change in Latitude (centimeters)	Change in Longitude (seconds)	Change in Longitude (centimeters)
1/2000			0	0	0	0
7/2000						
1/2001						
7/2001						
1/2002						
1/2003						
7/2003						

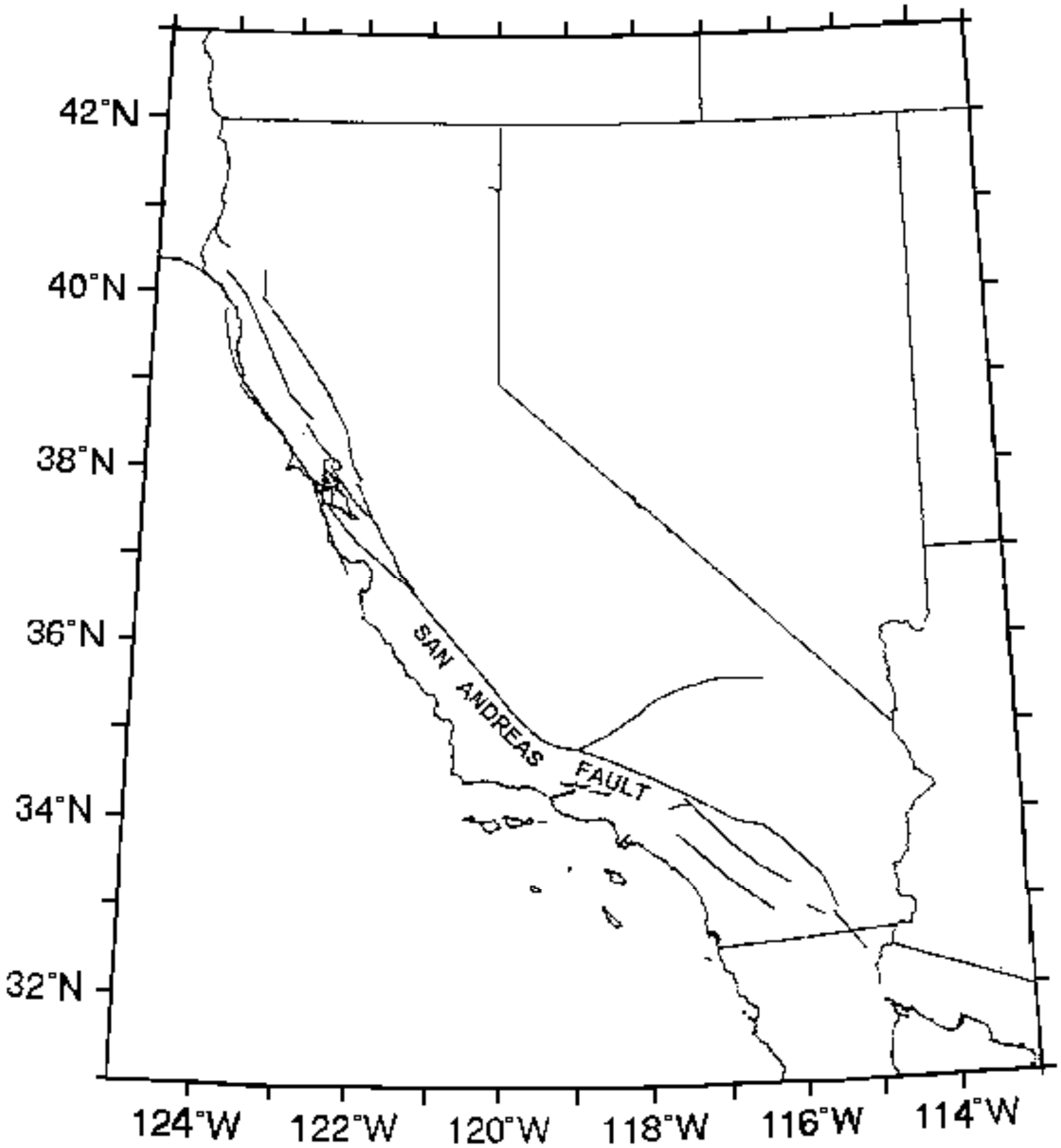
1\.
Share the calculations with your group members so that each person has the change in latitude in centimeters [Column E] and change in longitude in centimeters [Column G] for each of the 4 CORS sites. Put the information into the chart below.

Date	Change in Latitude (cm)			
	DHLG	MHCB	MONP	PPT1
1/2000				
7/2000				
1/2001				
7/2001				
1/2002				
1/2003				
7/2003				

Date	Change in Longitude (cm)			
	DHLG	MHCB	MONP	PPT1
1/2000				
7/2000				
1/2001				
7/2001				
1/2002				
1/2003				
7/2003				

2.
Graph the Change in Latitude vs. Date and Change in Longitude vs. Date.

3.
On the map below, draw in the change in location for each of the CORS sites. Use a scale of 1 cm change = 1 mm on the map. Then use your map to answer the questions that follow.



Questions:

Which 2 CORS sites are on the west side of the San Andreas Fault? What tectonic plate are they located on? In which general direction are they moving?

Which 2 CORS sites are on the east side of the San Andreas Fault? What tectonic plate are they located on? In which general direction are they moving?

Based on your knowledge of the cause of earthquakes, does it seems likely that there would be major earthquakes along the San Andreas Fault in either of these regions? Use your data to help support your answer.

GEODESY LESSON PLAN

Tracking Plate Movement – Teacher Answer Guide

Site: PPT1 (Pigeon Point)						
A	B	C	D	E	F	G
Date	Latitude (deg, min, sec)	Longitude (deg, min, sec)	Change in Latitude (seconds)	Change in Latitude (centimeters)	Change in Longitude (seconds)	Change in Longitude (centimeters)
1/2000	37° 11' 13.50222"	122° 23' 23.81732"	0	0	0	0
7/2000	37° 11' 13.50226"	122° 23' 23.81837"	0.00004	0.12	0.00105	2.59
1/2001	37° 11' 13.50226"	122° 23' 23.81911"	0.00054	1.67	0.00179	4.42
7/2001	37° 11' 13.50296"	122° 23' 23.82017"	0.00074	2.29	0.00285	7.04
1/2002	37° 11' 13.50376"	122° 23' 23.82087"	0.00154	4.76	0.00355	8.77
7/2003	37° 11' 13.50468"	122° 23' 23.82319"	0.00246	7.61	0.00587	14.50

Site: MHCB (Mount Hamilton)						
A	B	C	D	E	F	G
Date	Latitude (deg, min, sec)	Longitude (deg, min, sec)	Change in Latitude (seconds)	Change in Latitude (centimeters)	Change in Longitude (seconds)	Change in Longitude (centimeters)
1/2000	37° 20' 29.51711"	121° 38' 33.27491"	0	0	0	0
7/2000	37° 20' 29.51690"	121° 38' 33.27535"	-0.00021	-0.65	0.00044	1.086654143
1/2001	37° 20' 29.51683"	121° 38' 33.27593"	-0.00028	-0.87	0.00102	2.52
7/2001	37° 20' 29.51674"	121° 38' 33.27668"	-0.00037	-1.14	0.00177	4.37
1/2002	37° 20' 29.51719"	121° 38' 33.27691"	0.00008	0.25	0.00200	4.94
1/2003	37° 20' 29.51702"	121° 38' 33.27813"	-0.00009	-0.28	0.00322	7.95
7/2003	37° 20' 29.51701"	121° 38' 33.27848"	-0.00010	-0.31	0.00357	8.82

Site: MONP (Monument Peak)						
A	B	C	D	E	F	G
Date	Latitude (deg, min, sec)	Longitude (deg, min, sec)	Change in Latitude (seconds)	Change in Latitude (centimeters)	Change in Longitude (seconds)	Change in Longitude (centimeters)
1/2000	32° 53' 30.97932"	116° 25' 20.44522"	0	0	0	0
7/2000	32° 53' 30.97968"	116° 25' 20.44625"	0.00036	1.11	0.00103	2.67
1/2001	32° 53' 30.97994"	116° 25' 20.44701"	0.00062	1.92	0.00179	4.64
7/2001	32° 53' 30.97995"	116° 25' 20.44778"	0.00063	1.95	0.00256	6.64
1/2002	32° 53' 30.98073"	116° 25' 20.44876"	0.00141	4.36	0.00354	9.18
1/2003	32° 53' 30.98115"	116° 25' 20.45027"	0.00183	5.66	0.00505	13.10
7/2003	32° 53' 30.98131"	116° 25' 20.45082"	0.00199	6.15	0.0056	14.52

Site: DHLG (Durmid Hill)						
A	B	C	D	E	F	G
Date	Latitude (deg, min, sec)	Longitude (deg, min, sec)	Change in Latitude (seconds)	Change in Latitude (centimeters)	Change in Longitude (seconds)	Change in Longitude (centimeters)
1/2000	33° 23′ 23.30154″	115° 47′ 16.89546″	0	0	0	0
7/2000	33° 23′ 23.30144″	115° 47′ 16.89614″	-0.00010	-0.31	0.00068	1.76
1/2001	33° 23′ 23.30140″	115° 47′ 16.89652″	-0.00014	-0.43	0.00106	2.75
7/2001	33° 23′ 23.30117″	115° 47′ 16.89715″	-0.00037	-1.14	0.00169	4.38
1/2002	33° 23′ 23.30169″	115° 47′ 16.89764″	0.00015	0.46	0.00218	5.65
1/2003	33° 23′ 23.30128″	115° 47′ 16.89841″	-0.00026	-0.80	0.00295	7.65
7/2003	33° 23′ 23.30153″	115° 47′ 16.89871″	-0.00001	-0.03	0.00325	8.43

Date	Change in Latitude (cm)			
	DHLG	**MHCB**	**MONP**	**PPT1**
1/2000	0.00	0.00	0.00	0.00
7/2000	-0.31	-0.65	1.11	0.12
1/2001	-0.43	-0.87	1.92	1.67
7/2001	-1.14	-1.14	1.95	2.29
1/2002	0.46	0.25	4.36	4.76
1/2003	-0.80	-0.28	5.66	
7/2003	-0.03	-0.31	6.15	7.61

Date	Change in Longitude (cm)			
	DHLG	**MHCB**	**MONP**	**PPT1**
1/2000	0.00	0.00	0.00	0.00
7/2000	1.76	1.09	2.67	2.59
1/2001	2.75	2.52	4.64	4.42
7/2001	4.38	4.37	6.64	7.04
1/2002	5.65	4.94	9.18	8.77
1/2003	7.65	7.95	13.10	
7/2003	8.43	8.82	14.52	14.50

GEODESY LESSON PLAN

Geodesy Subject Review

1. The science of measuring and monitoring the size and shape of the Earth is ___________________.

2. By looking at the height, angles and distances between numerous locations on the Earth's surface, geodesists create a ___________________.

3. The Earth's surface rises and falls about 30 _____________ ______. everyday under the gravitational influences of the moon and the sun.

4. The Earth's outermost layer is called the _________________.

5. The plates that make up the Earth's outer layer ride atop a sea of molten rock called ___________________.

6. Plate ___________________. is the scientific discipline that looks at how the Earth's plates shift and interact, especially in relation to earthquakes and volcanoes.

WORD BANK

Aristotle
Geographic Information System
benchmarks
Global Positioning System
San Andreas Fault
datums
National Spatial Reference System
longitude
triangulation
time
magma
tectonics
masses
gravity
higher
gravimeters
Thomas Jefferson
geoid
unevenly
latitude
billionths
Continuously Operating Reference Stations
oblate
ellipsoid
geodesy
centimeters
horizontal
crust
vertical
differential
subsidence
refusal

7. The Greek philosopher __________________ is credited as the first person to try and calculate the size of the Earth by determining its circumference.

8. A method of determining the position of a fixed point from the angles to it from two fixed points a known distance apart. ____________________

9. The Earth is flattened into the shape of an _______________ sphere.

10. To measure the Earth, and avoid the problems that places like the Grand Canyon present, geodesists use a theoretical, mathematical surface called the __________________ that is created by rotating an ellipse around its shorter axis.

11. To account for the reality of the Earth's surface, geodesists use a shape called the __________________ that refers to mean sea level.

12. The earth's mass is __________________ distributed, meaning that certain areas of the planet experience more gravitational "pull" than others.

13. __________________ are sets of data that are the basis for all geodetic survey work. In the United States, horizontal and vertical datums make up a system called the ________ _________.

14. The __________________ datum is a collection of specific points on the Earth that have been identified according to their precise northerly or southerly location and easterly or westerly location.

15. The northerly or southerly location of a point on the Earth's surface is known as the point's _________________.

16. The easterly or westerly location of a point on the Earth's surface is known as the point's __________________.

17. Surveyors markpositions with brass discs or monuments called __________________.

18. Surveyors now rely almost exclusively on the ___________ to identify locations on the Earth.

19. The __________________ is where two plates of the Earth's crust meet, and is responsible for many earthquakes in California.

20. The __________________ datum is a collection of positions whose heights above or below mean sea level is known.

21. The traditional method for setting vertical benchmarks is called __________________ leveling subsidence land sinking

22. Gravitational attraction between two bodies is stronger when the __________________ of the objects are greater and closer together.

23. Because the Earth's mass and density vary at different locations on the planet, __________________ also varies.

24. In areas where the Earth's gravitational forces are weaker, mean sea level will __________________.

25. __________________ measure the gravitational pull on a suspended mass.

26. __________________ established the Survey of the Coast, which later evolved into the National Geodetic Survey.

27. The National Geodetic Survey uses markers made from long steel rods driven to __________________ (pushed into the ground until they won't go any farther).

28. GPS receivers calculate the distance to GPS satellites by measuring __________________.

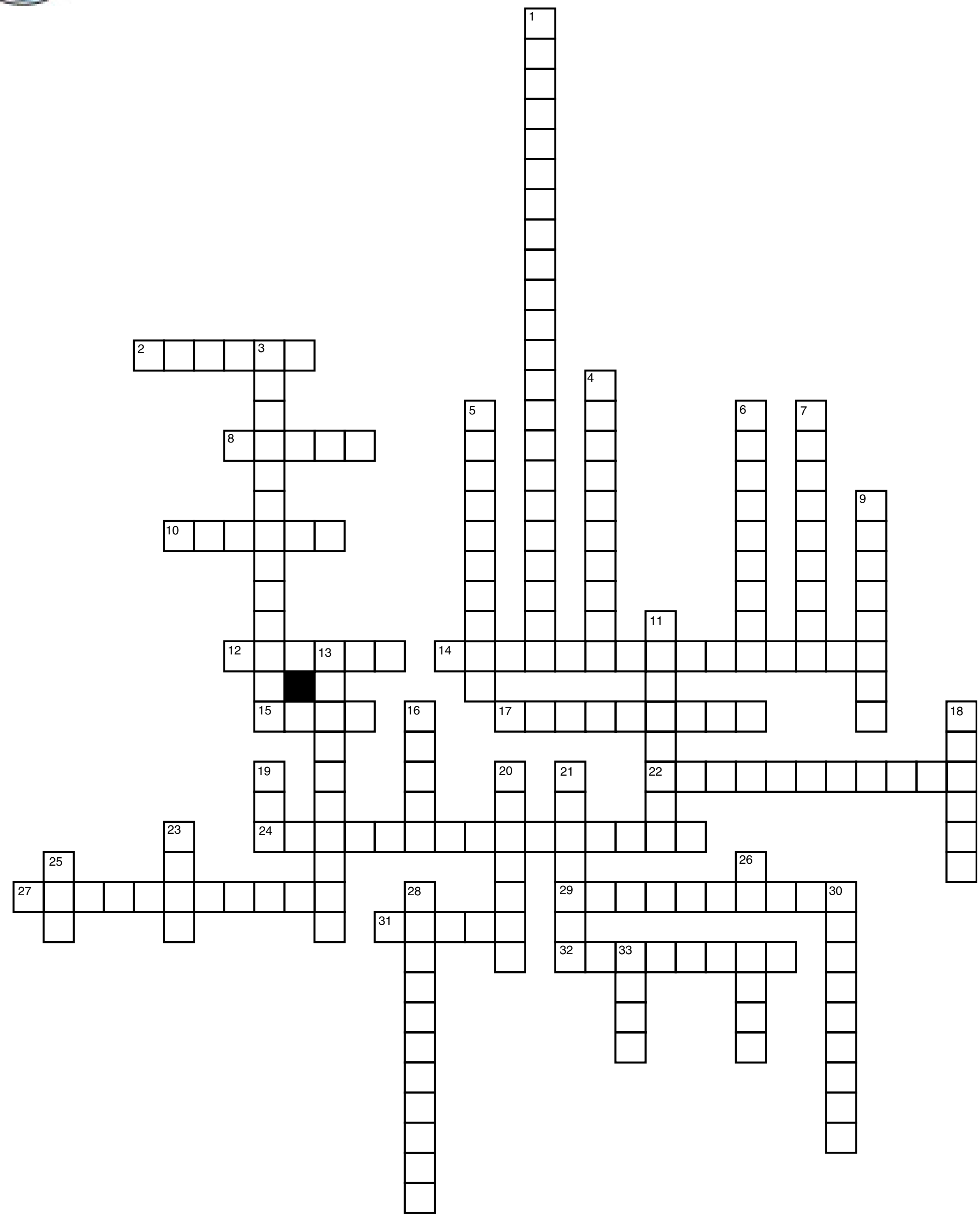
29. GPS satellites have very precise clocks that tell time within three nanoseconds or three __________________. (0.000000003) of a second.

30. ___________________ is a network of hundreds of stationary permanently operating GPS receivers throughout the United States that can be used to accurately determine position.

31. In a ___________________, specific information about a place—such as the locations of utility lines, roads, streams, buildings, and even trees and animal populations—is layered over a set of geodetic data.

GEODESY LESSON PLAN

Geodesy Subject Review: Crossword Puzzle



Across

2. The Earth is flattened into the shape of an _____ sphere.
8. The plates that make up the Earth's outer layer ride atop a sea of molten rock called _____
10. _____ are sets of data that are the basis for all geodetic survey work.
12. In areas where the Earth's gravitational forces are weaker, mean sea level will _____
14. Established the Survey of the Coast, which later evolved into the National Geodetic Survey. [2 words]
15. In the United States, horizontal and vertical datums make up a system called the _____. [abbrev]
17. The easterly or westerly location of a point on the Earth's surface is known as the point's _____.
22. The Earth's surface rises and falls about 30 _____ everyday under the gravitational influences of the moon and the sun.
24. The _____ is where two plates of the Earth's crust meet, and is responsible for many earthquakes in California. [3 words]
27. The traditional method for setting vertical benchmarks is called _____ leveling.
29. land sinking
31. The Earth's outermost layer is called the _____.
32. The northerly or southerly location of a point on the Earth's surface is known as the point's _____.

Down

1. By looking at the height, angles and distances between numerous locations on the Earth's surface, geodesists create a _____. [3 words]
3. A method of determining the position of a fixed point from the angles to it from two fixed points a known distance apart.
4. Surveyors markpositions with brass discs or monuments called _____.
5. GPS satellites have very precise clocks that tell time within three nanoseconds or three _____ (0.000000003) of a second.
6. The Greek philosopher _____ is credited as the first person to try and calculate the size of the Earth by determining its circumference.
7. Plate _____ is the scientific discipline that looks at how the

Earth's plates shift and interact, especially in relation to earthquakes and volcanoes.

9. The Earth's mass is _____ distributed, meaning that certain areas of the planet experience more gravitational "pull" than others.
11. The _____ datum is a collection of positions whose heights above or below mean sea level is known.
13. The _____ datum is a collection of specific points on the Earth that have been identified according to their precise northerly or southerly location and easterly or westerly location.
16. To account for the reality of the Earth's surface, geodesists use a shape called the _____ that refers to mean sea level.
18. Gravitational attraction between two bodies is stronger when the _____ of the objects are greater and closer together.
19. Surveyors now rely almost exclusively on the _____ to identify locations on the Earth. [abbrev]
20. Because the Earth's mass and density vary at different locations on the planet, _____ also varies.
21. The National Geodetic Survey uses markers made from long steel rods driven to _____ (pushed into the ground until they won't go any farther).
23. _____ is a network of hundreds of stationary permanently operating GPS receivers throughout the United States that can be used to accurately determine position. [abbrev]
25. In a _____, specific information about a place—such as the locations of utility lines, roads, streams, buildings, and even trees and animal populations—is layered over a set of geodetic data. [abbrev]
26. The science of measuring and monitoring the size and shape of the Earth
28. _____ measure the gravitational pull on a suspended mass.
30. To measure the Earth, and avoid the problems that places like the Grand Canyon present, geodesists use a theoretical, mathematical surface called the _____ that is created by rotating an ellipse around its shorter axis.
33. GPS receivers calculate the distance to GPS satellites by measuring _____.