Integrating Computers into the Field Geology Curriculum

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ABSTRACT

The Field Geology course at Rutgers University incorporates computers in all projects, including the use of an Electronic Total Station (ETS) and portable Global Positioning System (GPS) receivers in collecting field data. The ETS determines the distance and bearing to sighted points and calculates their spatial coordinates and elevations; it then stores the results in a data-logger. GPS receivers provide absolute coordinates for stations occupied by the ETS itself or for outcrop locations during mapping. The ETS is faster and more accurate than traditional surveying methods, and virtually eliminates operator and transcription errors. Furthermore, ETS data can be downloaded directly to a computer, where the data can be plotted, manipulated, and contoured.

We use the ETS/GPS system to collect topographic data and map geologic contacts in a clay pit in the New Jersey coastal plain. Station locations are plotted and contoured by computer. A computer-aided drafting (CAD) program is then used to put the finishing touches on the geologic/topographic map. The ETS/GPS system is also used to construct a detailed topographic map of a stream channel and adjacent flood plain. Other computer applications include (1) using CAD programs to draw stratigraphic sections and to prepare presentation-quality geologic maps; (2) using spreadsheet and graphic programs to plot topographic profiles; and (3) using stereographic projection programs to plot and interpret fracture data.

Keywords: Geology—Field Trips and Field Study; Education—Computer Assisted

INTRODUCTION

The use of computers in many aspects of geological instruction has been increasing over the last decade. A notable exception to this trend involves field methods courses. This is unfortunate in that these courses are commonly the capstone of the geology curriculum. Any computer applications that are used in field methods courses rely on analysis, interpretation, and presentation of data collected by conventional means in the field. Consequently, the original data must be entered into the computer application by hand before any type of analyses or interpretations may be undertaken. In many instances, this is unavoidable, in that there is no way to download the field data to a computer. A notable example concerns spatial data collected by various surveying equipment (alidades, theodolites, transits, automatic levels, etc.). The advent of Electronic Total Stations (ETS) and Global Positioning System (GPS) receivers now makes it possible to collect a wide range of spatial data in the field, store the data in a data logging unit, and then download the data to a personal computer. This new technology allows us to use computers in both the classroom and the field, where they will allow students to collect data more quickly, easily, and reliably than was the case previously. This will also afford the students more time to analyze and interpret the data they have collected.

This year, we substantially revised the Field Geology course at Rutgers to incorporate computers in some aspects of data collection and nearly all aspects of analysis and presentation while retaining most of the traditional field techniques (mapping on a topographic base and air photo, measuring stratigraphic sections, surveying with automatic levels and plane tables and alidades). In this paper, we present the Field Geology curriculum at Rutgers University as an example of how computers can be integrated into field courses. We also briefly describe the various computer applications used in this course, and present an appraisal of the merits and drawbacks of this approach.

The three-credit Field Geology course is required of all geology majors who do not elect to attend an outside field camp. Prerequisites include Sedimentology, Stratigraphy, and Structural Geology. The course is typically taken in the senior year as the capstone of our curriculum and is centered around a number of field-based projects which stress active learning: students in small field groups (2-3 students) must collect, analyze, and interpret field data utilizing a variety of field methods. The class meets for eight days prior to the start of the fall semester and then for six hours on Fridays for the first eight weeks of the semester. In the past five years, enrollments have ranged from 9 to 13 students, depending on how many students go away to field camps.

The Field Geology syllabus is presented in Table 1. Computer applications fall into two broad types: (1) those used to manipulate, plot, and present geologic data obtained by traditional field methods, and (2) those used to obtain field data directly. In the following two sections, we describe these various computer applications with respect to the main Field Geology projects and also briefly describe how the field-based computer systems have been incorporated in field projects in other geology courses. Here, we limit our discussion to Macintosh-based computer applications; PC-based applications are briefly described in the Discussion section.

Project	Field Tasks	Office Tasks
Preliminary Exercises	Pace-and-compass mapping of sidewalks on academic quadrangle, Rutgers University	*Plot pace-and-compass data using CANVAS* Construct geologic maps from point data; prepare cross sections
Godfrey Ridge	Tape-and-compass mapping of trail system Reconnaissance mapping of Godfrey Ridge and Minisink Hills using topographic base & aerial photograph Measured stratigraphic section, Minisink Hills Structural analysis of folds and minor structures at Interchange Quarry	Construct geologic map and cross sections on mylar *Draft stratigraphic section using CANVAS* *Draft revised geologic map using CANVAS* Written report
Newark Basin	Reconnaissance mapping of Busch and Livingston campuses on topographic base Measured stratigraphic section, Douglass campus Collect joint orientation data, Busch and Livingston campuses	Project drill hole data to surface *Draft geologic map using CANVAS* Draft geologic cross section (use of computers is optional) *Draft stratigraphic section using CANVAS* *Plot fracture data using STEREONET* Written report
Sayreville Clay Pit	*Use ETS/GPS to collect topographic and geologic data from SE wall of clay pit* Use plane table & alidade to collect topographic data Use automatic level to map lake margin Measured stratigraphic section	*Prepare topographic, geologic, and 3-D fishnet map of ETS/GPS data using EXCEL, SURFACE, and CANVAS* *Prepare topographic map of plane table data using CANVAS and SURFACE* *Plot stratigraphic section using CANVAS* Written report
East Branch Perkiomen Creek	Use automatic level to measure profiles across stream channel Use automatic level to transfer elevation from known benchmark to control points at profile locations Measure flow velocities and pebble b-axes; geologic characterization of channel and flood plain *Use ETS to map part of channel and floodplain*	*Plot topographic profiles of each transect using CRICKETGRAPH and compare with profiles obtained during previous surveys* *Prepare contour map of ETS data using EXCEL and SURFACE* Use velocity and clast size data along with channel geometry to perform various hydraulic calculations

Table 1: Field Geology curriculum as implemented in Fall 1995. Items in *italics* involve the use of computers.

USE OF COMPUTERS IN PLOTTING, MANIPULATING, AND PRESENTING FIELD DATA
Preliminary Exercises

Following overview lectures on field procedures and methodology on the first day of the course, students are given a relatively simple exercise in which they must prepare a pace-and-compass map of the walkways on the academic quadrangle adjacent to the geology building. Students also use Bruntons, pace, and eye height to measure the heights of light poles and the strike and dip of sloping sidewalks. Following data collection, students plot their maps using the drawing program *CANVAS 3.5.4* (Deneba, 1995) for the Macintosh. These preliminary exercises provide the students with the opportunity to refamiliarize themselves with the various uses of the Brunton compass and also provide a relatively straightforward introduction to the operation of *CANVAS*, which is routinely used in all Field Geology projects. We also hand-out additional exercises on interpreting geologic map patterns, constructing geologic cross sections, and constructing a geologic map from "point data" that simulate outcrop stations utilized in actual geologic mapping.

Godfrey Ridge Project

This seven-day project takes place in the Valley and Ridge Province near Stroundsburg and Delaware Water Gap, Pennsylvania. The study area consists of folded Silurian-Devonian limestones, sandstones, conglomerates, and shales (Epstein and Epstein, 1969; Epstein et al., 1967). Students are provided with an aerial photograph and paper copies of a topographic base map, which was scanned, digitized, and enlarged from the U.S.G.S. Stroudsburg and East Stroudsburg 7.5" topographic quadrangle maps. A Universal Transverse Mercator (UTM) grid has also been added to the base map, which provides a useful reference frame for plotting stations whose coordinates were determined with GPS receivers (see below). Students conduct tape-and-compass traverses along a network of foot trails. *CANVAS* is used to prepare a map of the trails, which is then printed out at the same scale as the base map. Students then manually trace the trails onto their copies of the base map. The trails provide a handy geographic reference during mapping, which is conducted by students working in pairs or triples during four days of field work. Additional field exercises involve measuring a detailed stratigraphic section through the contact between the

Oriskany Group and the Esopus Formation and analyzing the structural relationships (cleavage-bedding relations, slickenlines related to flexural-slip folding, etc.) of a well-exposed fold in an old quarry.

Following the field work, students hand-draft their maps and cross sections on mylar or tracing paper. After these maps are corrected and graded, students are provided with *CANVAS* files containing the same topographic base map they used in the field work. The students use *CANVAS* to draft and overlay a geologic map on the base map. The geologic map includes formations and contacts, strike and dip symbols for bedding and cleavage, fold axial traces, and a complete key (formations, ages, and descriptions as well as explanations of all structure symbols). The filled polygon tool is used to draft the formations and their contacts (which can be either solid or dashed); the unfilled polygon (polyline) tool is used in conjuction with arrowed lines to draft fold axial traces; using the azimuthal coordinate system in *CANVAS*, the line and text tools are used to draft strike and dip symbols. The final computer-drafted maps are printed on a color printer. Students are graded on the "correctness" of the geologic map and legend as well as the overall quality of the presentation. The rationale behind requiring students to prepare these computer-drafted maps is as follows: (1) students learn how to use a computer drafting program to prepare presentation-quality geologic maps, and (2) in drafting these computer maps, the students have a chance to carefully observe (and hopefully learn from) the mistakes that were made on the hand-drafted maps. Students also quickly learn that major and minor changes can be made relatively quickly and easily to their computer maps, e.g., changing colors of the formations, changing the map from color to grayscale or black and white fill patterns, and enlarging or reducing the printed dimensions of the map.

As part of the Godfrey Ridge project, students also draft their measured stratigraphic sections using *CANVAS*. The ruler in *CANVAS* is set to the desired vertical scale of the stratigraphic column (e.g., 1 cm = 5 m). Rectangular objects representing the various stratigraphic units can be quickly drafted. The heights of these rectangles can be easily adjusted to conform to the measured thicknesses; the widths can also be adjusted to conform to a grain-size scale. These rectangles are given black and white fill patterns corresponding to the predominant lithology and are then stacked and left-aligned into a columnar section. Special symbols for sedimentary structures and fossils are easily added. Finally, descriptive text, scale, and legend are added to the columnar section (Figure 1).

The final part of the project involves preparing a geologic report on the study area. These reports are edited for style, grammar, and content; graded; and returned to the students, who have the option of re-doing the written report for an improved grade.

Newark Basin Project

This three-day project involves outcrops of the Triassic-Jurassic Newark basin located in and around the campuses of Rutgers University in New Brunswick and Piscataway, New Jersey. The goal of the mapping exercise is to prepare a geologic map of the Busch and Livingston campuses. This area is underlain by the Passaic Formation, which consists of predominantly red massive mudstone but which also contains distinctive non-red marker units. These non-red units have been identified in the Rutgers drill hole (Olsen et al., 1996), and students use the subsurface data to project the marker beds to the surface. Field mapping focuses on tracing these marker beds through the study area. The marker beds are deformed by normal faults and associated drag folds. Students plot their field data on paper copies of a computer-drafted topographic base map, and then use CANVAS to draft their geologic maps on the digital base map. Many students also use *CANVAS* to draft their geologic cross sections. Students find that the zoom-in feature allows them to draft the cross sections, which contain a large number of closely spaced marker units, more carefully than is possible by hand.

Students also measure a stratigraphic section of lake beds displaying cyclical alternations in color and sediment fabrics. Once again, *CANVAS* is used to draft the stratigraphic section. Students also measure a population of joints and use the program *STEREONET 4.9.6a.* (Allmendinger, 1995) to prepare scatter plots, Kamb contour plots, and rose diagrams (Figure 2). A written report integrating the drill core, map, fracture, and outcrop stratigraphic section data is also required.

USE OF COMPUTERS TO COLLECT FIELD DATA
Electronic Total Station (ETS)

The ETS (Figure 3a) is a modern surveying instrument package (see Table 2 for list of equipment) that determines the distance to a rod-mounted reflecting prism (Figure 3b) using the travel time of reflected low-intensity infrared laser light rays. The instrument (Fig. 3c) automatically calculates the horizontal distance and compass bearing to the prism as well as the change in elevation between the instrument and the sighted point, and can express these quantities in terms of relative or absolute coordinates (e.g., northing, easting, and elevation; Table 3). Corrections are automatically made for the curvature of the Earth and changes in the speed of light due to changes in temperature and barometric pressure. The range of the instrument depends on the sophistication of instrument and the ambient weather conditions. A basic unit (utlizing one prism) has a range of about 1 km. Precision is ±1.5 mm; accuracy is ±5 mm.

Gun	Environmental case
Optical plummet tribrach	Rod with level
Battery charger	Prism w/target
Tripod	Computer
Plumb bob	Communications software
Folding ruler	Stakes
Mounting bracket	Spare batteries
Data logger	Walkie-Talkies
Cable for connecting data logger to gun	Cable from computer to data logger

Table 2: List of ETS equipment.

Station Number	Northing (ft)	Easting (ft)	Elevation (ft)	Description
69	94680107	10160338	118	Topography
70	94680614	10160381	182	Topography
71	94680550	10160385	173	Base, Formation E
72	94680502	10160386	165	Base, Formation A
73	94680440	10160374	160	Base, Formation B
74	94680359	10160381	145	Topography

Table 3: Sample ETS data.

About 4 seconds are required to take and store one measurement with the ETS. Data are stored in a data logging unit (Figure 3d); a basic unit can hold about 2500 measurements. In addition to the spatial data, the data logger also records station numbers and a brief description of the station (up to 10 alphanumeric characters). Once set up, the ease and rapidity of operation allow the user to cover a large area rapidly or a small area in great detail rapidly. The data logging unit functions as an electronic field notebook and thus eliminates the need for transcribing data by hand, which eliminates associated human errors. Furthermore, because the instrument takes its own readings, there is no operator error, which is commonly the case with other surveying instruments.

An important consequence of the faster surveying with the ETS is the increased time it gives the user to concentrate on geologic features. The ETS transforms detailed surveying from a time-consuming, often frustrating process into a simple tool to be used by the field geologist. Given the speed with which data are collected with an ETS, features such as geological contacts, outcrops, and contours can be mapped as almost continuous lines with closely spaced points, thus nearly eliminating the need for any freehand drawing (Philpotts et al., 1995).

The instrument always needs to know its location. The coordinates of the instrument's occupied point can be (1) determined using GPS receivers (see below), (2) arbitrarily specified, or (3) determined by shooting bearings to two known points. The instrument can be moved to new location after the coordinates of the new occupied point are determined by shooting a bearing to it.

The data logging unit downloads its information directly to a personal computer (Macintosh or PC) for subsequent analyses, obviating the need to manually input the data into other computer programs. We use the communications program *Z-TERM 1.0.2b* (Alverson Software, 1994) to download from the data logger to a Macintosh. The transferred data files are saved as comma-delimited text that can be read by the spreadsheet program *EXCEL 4.0* (Microsoft Corp., 1992). Data files can then be easily sorted and subdivided; for example, all stations occurring along a given geologic contact can be saved as a separate file. The data files are then saved as text files, which can then be read by the plotting program *SURFACE III+ v. 2.6* (Kansas Geological Survey, 1995). *SURFACE* can be used to prepare simple plots of station locations; station numbers, descriptions, or station elevations can be plotted next to the station locations (Figure 4a). Various types of interpolated data grids and styles of topographic maps may be generated from the elevation data (Figures 4b and 5). Mul-

tiple data files can be plotted on the same map, thus allowing stations along different contacts to be plotted using different symbols and/or colors (Figure 4b). The various plots generated in *SURFACE* are then saved as PICT files and exported into *CANVAS*, which can be used to "connect the dots" for stations located along geologic contacts, faults, etc. Contouring errors (see discussion below) can also be corrected at this stage. Structure symbols, legends, titles, etc. can also be added to the topographic/geologic map (Figure 4c).

Global Positioning System (GPS)

The Global Positioning System is based on 24 satellites in geosynchronous orbit. It works by satellite ranging to a hand-held receiver, which computes its own position (e.g., latitude, longitude, and elevation) on the Earth. The hand-held receivers (Figure 3e) work best in open areas where they have an unobstructed line of sight to multiple satellites. Spatial locations can be supplied in latitude/longitude or Universal Transverse Mercator (UTM) coordinates. Errors associated with X-Y coordinates are up to 15 m (subject to U.S. Department of Defense 100 m selective availability) or up to 5 m if differential GPS service or a costly base station is used. Using the relatively inexpensive hand-held receivers without a base station, elevation (Z) data are not reliable. We use our GPS system to determine X-Y coordinates of a benchmark or the initial occupied location for the ETS. GPS units also accompany us on the Godfrey Ridge and Newark basin mapping exercises and supply the students with the coordinates of critical stations.

Sayreville Project

The field area for this two-day project is the Sayreville Pit, an abondoned clay pit in the New Jersey Coastal Plain. Three Cretaceous stratigraphic units and Quaternary alluvium are present in the study area (e.g., Jengo, 1995). Erosion of the unconsolidated deposits has created a badlands topography, which is too detailed, complex, and changeable to show on conventional 7.5" quadrangles. Students use the ETS and GPS systems to collect topographic data within the quarry and to map the contacts between the four geologic units. Electronic data files are downloaded to a Macintosh, which is then used to prepare topographic and geologic maps using the programs *EXCEL*, *SURFACE*, and *CANVAS* as outlined above. *SURFACE* is also used to prepare a 3-D topographic map (fishnet diagram) of the study area (Figure 5).

The Sayreville project also provides students with the opportunity to use other surveying equipment and to com-

pare these with the ETS system. Aside from the instructional value, this is also necessary in that all students cannot use the ETS system at once. An autolevel is used to map out the perimeter of a lake that fills the center of the quarry; students are required to plot the lake shoreline by hand while in the field. A plane table and alidade is also used to obtain topographic data from a small part of the quarry. Station locations are plotted in their proper relative positions directly in the field (e.g., Compton, 1985). These field maps are then optically scanned and imported into *CANVAS*, within which it is easy to obtain the relative X and Y coordinates of the stations--simply place the cursor over a station, and coordinates are displayed in a window at the bottom of the screen. X, Y, and Z coordinate data are then tabulated (by hand), entered in *EXCEL*, and then transferred to *SURFACE* for plotting and contouring. Students are also given the option of contouring the elevations by hand, but so far none has selected that option!

East Branch Perkiomen Creek Project

This project provides students with the opportunity to further use surveying equipment and to apply these skills to study modern fluvial processes. The study area is located near the headwaters of East Branch Perkiomen Creek, near Bedminster, Pennsylvania. As a result of a flow-diversion project to supply cooling water to the Limerick Nuclear Generating Station, discharge within the creek has been artificially elevated by up to 450% (Ackermann, 1994) in summer months. Through repeated surveying of the same profiles, students have the opportunity to gauge anthropogenically induced geomorphic changes. Elevation data along four long-established cross sections are obtained by surveying with an automatic level. The topographic data are plotted using *CRICKETGRAPH III v. 1.5* (Computer Associates, 1993) (Figure 6a). The ETS can also be used for this purpose, but because data collection, transcription, and data entry in *CRICKETGRAPH* are relatively rapid and easy, there is not much advantage to using the ETS. Furthermore, instrument setup is much more rapid for the autolevel than for the ETS. Instead, the ETS system is used to obtain detailed topographic data of a part of the channel and adjacent floodplain. The data are plotted and contoured using *SURFACE*. The plots are then imported to *CANVAS* for final touch-up.

Other tasks performed during this exercise include: (1) transferring elevations from a benchmark to the local benchmarks present at each of the four transects using an automatic level; (2) measuring flow velocities with a current meter; and (3) measuring b-axes of pebbles (students enter the clast size data in *EXCEL*, sort it, and then read off the values of the 16th, 50th, and 84th percentiles). In a written report, students assess the amount of geomorphic change over time and use hydraulic equations to calculate discharge, Froude number, Reynolds number, shear stresses, and the maximum clast sizes that can be entrained by the flow.

Use of ETS and GPS in Other Courses

In addition to the Field Geology course, we have also used the ETS on field trips for the Sedimentology and Introduction to Geophysics courses. The ETS was used at Sandy Hook, New Jersey, to measure a beach profile and to construct a topographic map of the beach. ETS data were then downloaded to a Macintosh Powerbook computer while we were still in the field. The beach profile was then plotted using *CRICKETGRAPH* (Figure 6b). The significance of this profile was discussed with the students while we were still at the beach! The Introduction to Geophysics class obtained a series of seismic refraction profiles across part of Rutgers' Busch Campus. The ETS was used to determine the relative elevations of all the geophone locations so that a statics correction could be made to the two-way travel-time data.

DISCUSSION

At the end of 1995 Field Geology course, all students received a detailed questionnaire about the content and workload of the course. Six of 11 students returned the evaluations. The discussion below is based on the results of the evaluation and our own observations and impressions.

Students appreciate being able to learn more about using computers. However, the use of computers in a Field Geology course should not reduce the number of field exercises. Furthermore, if computers are to be successfully used in a field geology course, they must be an integral part of data collection, manipulation, and/or presentation. In addition, the required task should generally be easier and/or faster to do on the computer than by other means. If not, students must be told explicitly the advantages of using the computers (e.g., a digital map can be printed at almost any size; it is easy to make changes; the output is often publication-quality). Students dislike exercises that they feel are repetitive (e.g., measuring and drafting three stratigraphic sections). We plan to revise our course by deleting one of the stratigraphic sections and giving the students a choice of drafting the Newark basin geological map by hand or on the computer.

Computer facilities must be adequate to allow all students the opportunity to complete the required exercises, especially during crunch time (the evening before an assignment is due). Given that students overwhelmingly prefer Macintoshes to PC's, the number of Macintoshes in our departmental computer room (6) was barely adequate for the number of students (11). When students elected to use a PC, the four in our computer room were adequate.

We believe that is important to allow students to choose between Macintoshes and PC's. Perhaps even more importantly, we believe that students should be familiar with both platforms. In order to encourage greater utlization of the PC's, we have selected programs that are similar on both platforms. With respect to *CANVAS*, our most heavily utilized program, the PC and Mac versions are virtually identical, and files can be exchanged across platforms; the same is true for *EXCEL*. Although not identical to *SURFACE*, Gridzo in *ROCKWORKS* (RockWare, 1995) provides plotting and contouring options for the PC.

Many students are unfamiliar with the basic operation of computers, and require preliminary training. Some of this is provided in other courses. At Rutgers, we now use computer exercises in Sedimentology, Stratigraphy, Petrology, Structural Geology, and Geophysics, as well as Geological Modeling (an optional course). Nonetheless, the students do still require detailed instructions on the procedures for using the various computer applications. These

are provided in a bound "Field Geology Manual," which is given to students at the start of the course. In addition to the recipes for using the various computer programs, the manual also contains numerous how-to field procedures and background about the various field projects. Although the manual is a large help to students who actually read it, questions and problems still abound. The instructor/T.A. must be prepared for at least as many computer-related questions as geology-related questions. Furthermore, they must deal with system crashes, printer problems, bad floppy disks, etc., especially if there is no computer consultant within the department.

Computers offer many benefits: graphing, spreadsheet, and stereonet programs save the user a great deal of time. Drafting programs offer very fine precision and allow the user to make changes quickly and easily. However, computers also have their shortcomings of which students need to be aware. A good example concerns the output of contouring programs. Close examination of Figure 4b shows that a large number of the contour lines are misplaced, especially in the stream valleys. Fortunately, *SURFACE* outputs its contour lines as polyline objects, which can be edited relatively easily in drafting programs like *CANVAS*. The corrected contour lines appear in Figure 4c.

In summary, the computer-oriented Field Geology course at Rutgers University allows students to become proficient with a large number of computer applications while still retaining all of the instruction on the various fundamental and classical field procedures. We feel that the increased use of computers in this course has enhanced the marketability of our majors.

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Composite Columnar Section Along Minisink Hills, Monroe County, Pennsylvania

By Phillip Martell and Josef Chmielowski
September 1, 1995

Measured with a tape measure

Based on 1:24000 Stroudsburg
(1973) and East Stroudsburg
(1993) USGS Topo Quads

X= N 41° 00'00"
W 075° 08'31"

MN N
10.5°

500
600

Series	Formation	Thickness in feet	Feet above base	Graphic columnar section	Description	Key

Series: Lower Devonian

Formation (upper): Esopus Formation — Thickness 5.07

Formation (lower): Oriskany Group — Thickness 22.08

Description:

- Well-laminated, dark gray shale. Fe staining and cleavage prominant.
- Covered interval
- Fe stained shale. Brachiopods and other fossils present.
- Shale with interbedded chert nodules. Brachiopods present.
- Moss-covered limey shale. Silt sized grains are HCl reactive.
- Covered interval
- Conglomeratic ss. Clasts ~ 5.0 mm Sub - horizontal jointing present throughout layer. HCl rxn.
- M.G. - F.G. qtz ss. Clast supported, wormy looking holes in bed.
- M.G qtz ss. Clasts fine upward and are sub - rounded.
- Cong. qtz ss. Clasts are rounded to sub - rounded.
- C.G. clast supported, qtz ss. CaCO$_3$ matrix, grains translucent.
- F.G. S.S. HCl rxn.
- C.G. qtz ss. Clasts well rounded, HCl rxn, Fe stained.
- F.G. qtz ss, HCl rxn, random clasts ~ 2.0mm.
- C.G. qtz ss, grains well rounded, HCl rxn, clasts ~ 0.5 - 5.0mm.
- F.G. ss, well sorted with CaCO$_3$ matrix. Fossils present. Gray-green color.
- F.G. ss. Clasts uniform in size.
- Qtz cong. clasts ~ 1.0 - 7.0mm. Clast supported.
- F.G. ss, cleavage present, chert nodules parallel to bedding. Buff/gray color.
- F.g. qtz ss with chert nodules. Lt. gray.
- C.G. qtz ss, clasts~0.5 - 5.0 mm.
- Black chert bed, fine grained.
- Covered interval
- F.G. qtzss. Chert nodules and layers present. Weathered light brown, fresh gray. Fe staining.

Key:

F.G. - Fine grained

M.G. - Medium grained

C.G. - Coarse grained

Cong - Conglomeratic

Rxn - Reaction

ss - Sandstone

- Sandstone
- Conglomerate
- Shale
- Laminated shale
- Limey shale
- Chert
- Quartz clast
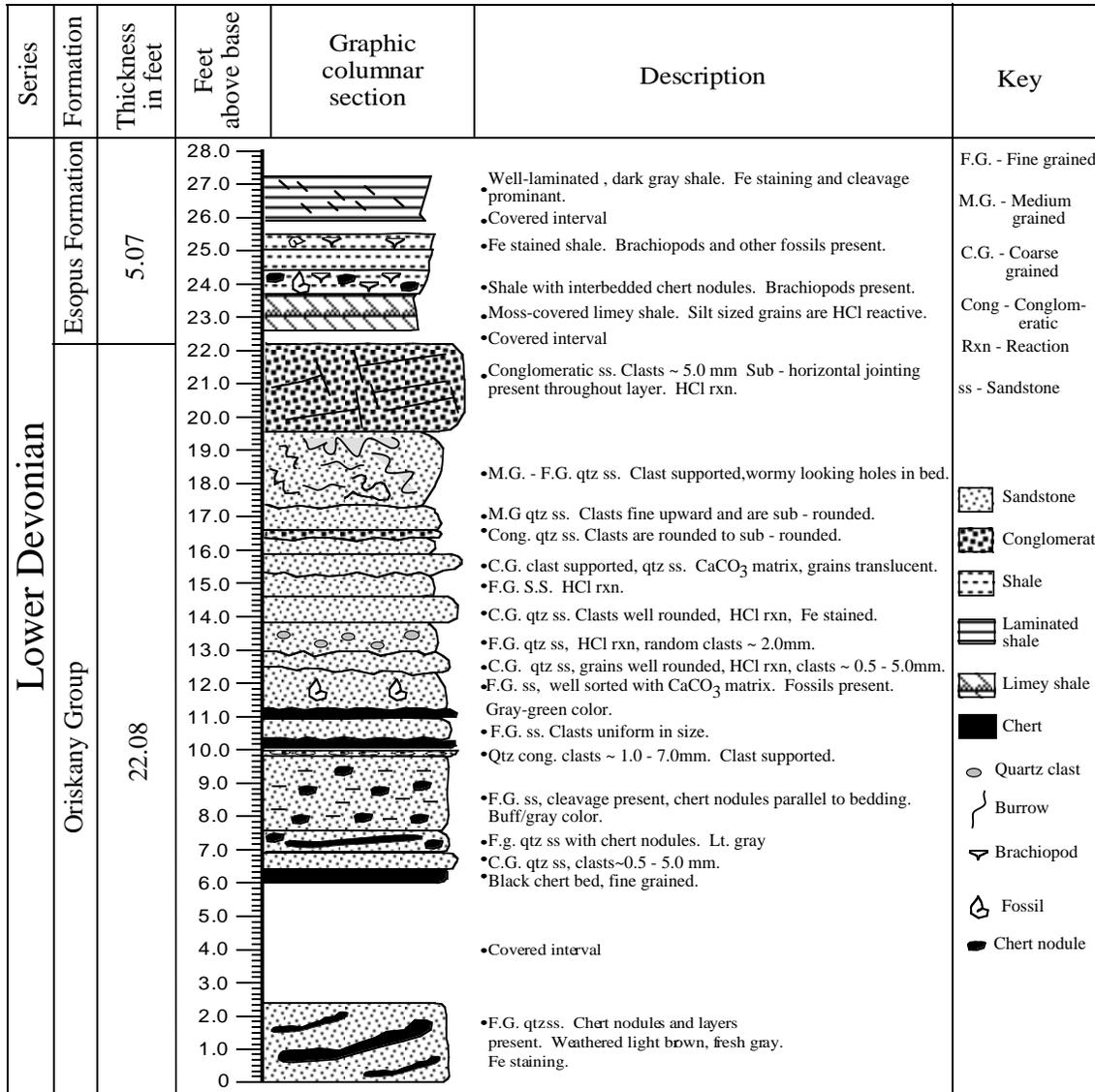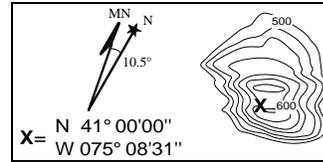- Burrow
- Brachiopod
- Fossil
- Chert nodule

Figure 1: Stratigraphic section prepared by Phillip Martell using CANVAS as part of the Godfrey Ridge project. The section was measured by Martell and Josef Chmielowski. Martell's original diagram has been altered slightly to conform to publication requirements.
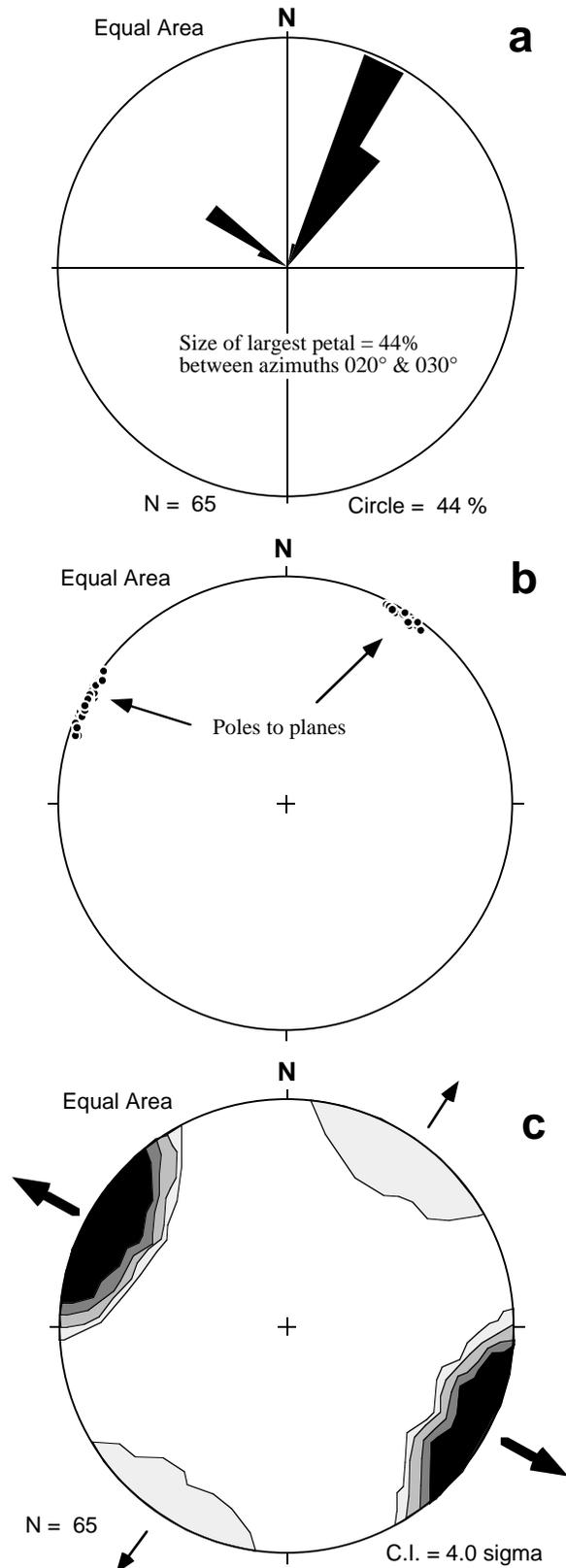
Figure 2: Equal-area stereographic projections of joints in the Passaic Formation of the Newark basin measured in stream outcrops on the Busch Campus of Rutgers University, Piscataway, New Jersey: (a) rose diagram of joint strikes; (b) scatter plot of poles to joints; and (c) Kamb contour plot of poles to joints, with major and minor extension directions indicated by arrows. The data were collected by Phillip Martell and plotted in STEREONET; the graphics files were exported to *CANVAS* for final layout. Martell's original diagram has been altered slightly to conform to publication requirements.

Figure 3: (a) Bonnie Eiben looking through the gun of an ETS in the Sayreville Pit, Sayreville, New Jersey. (b) Walter Svekla holding rod-mounted prism and walkie-talkie in the Sayreville Pit. (c) Closeup view of the gun and optical tribrach. The LCD display of the gun shows the current vertical angle (measured from the vertical) and horizontal azimuth (measured with respect to north) in degrees, minutes, and seconds. (d) Closeup view of the data logger. Within the LCD display: OC refers to occupied point (the current location of the gun and tripod) and gives its station number; FS refers to front sight (a station surveyed by the ETS) and gives its station number ; BS refers to back sight (a station used to establish the position of the occupied point) and gives its station number; azimuth is the horizontal angle in degrees, minutes, seconds (DD.MMSS) from the OC to the current FS); Zenith ang is the vertical angle (in DD.MMSS) between OC and FS; slope dist. is the distance (in feet) between OC and FS; Desca is a description of station 1376; HI is the height of the instrument (in feet); and HR is the height of the rod (in feet). Operations are key- and menu-driven. (e) Closeup of GPS receiver. Under "POSITION", the instrument displays the UTM coordinates of a station (Edison, New Jersey) within Zone 18T .
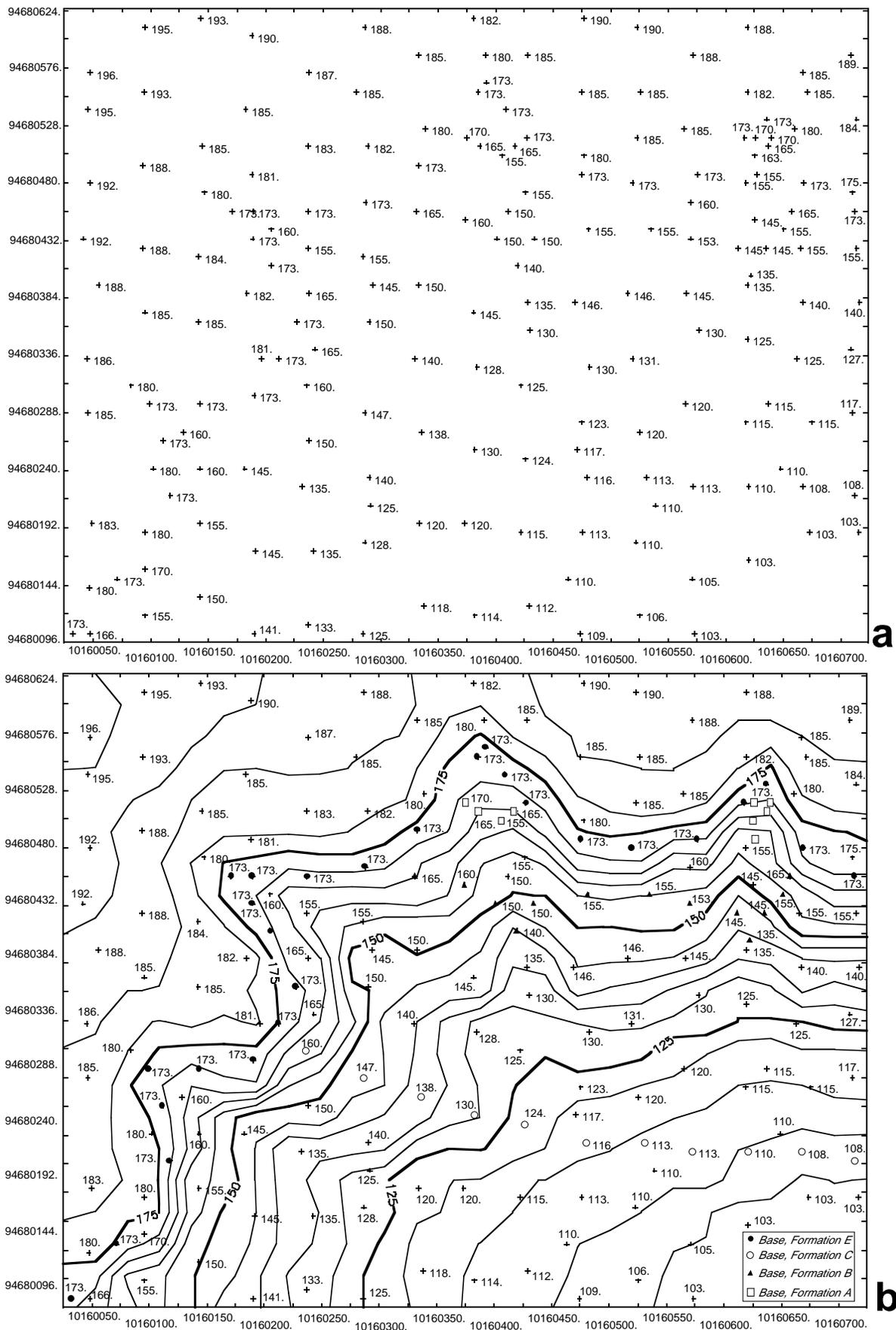
Figure 4: Example of how ETS-like data can be used to prepare a topographic and geologic map using SURFACE and CANVAS. To prepare this figure, a hypothetical topographic/geologic map was first drafted in CANVAS. The X, Y, and Z coordinates for 190 "stations" were read off in CANVAS (for real-world examples, the ETS would obtain this data), entered in EXCEL, and then transferred to SURFACE. (a) Posting map of the stations with elevations; grid numbers simulate a UTM-type grid. (b) Contour map of elevation data from (a). Also shown with different symbols are stations located along geologic contacts. This diagram was then exported to CANVAS.

Easting (ft.)

Contour interval: 5 ft.

0   25   50   75   100 ft

0   10   20   30 m

N

Tertiary | Te. | Formation E
Cretaceous | Kd | Formation D
| Kc | Formation C
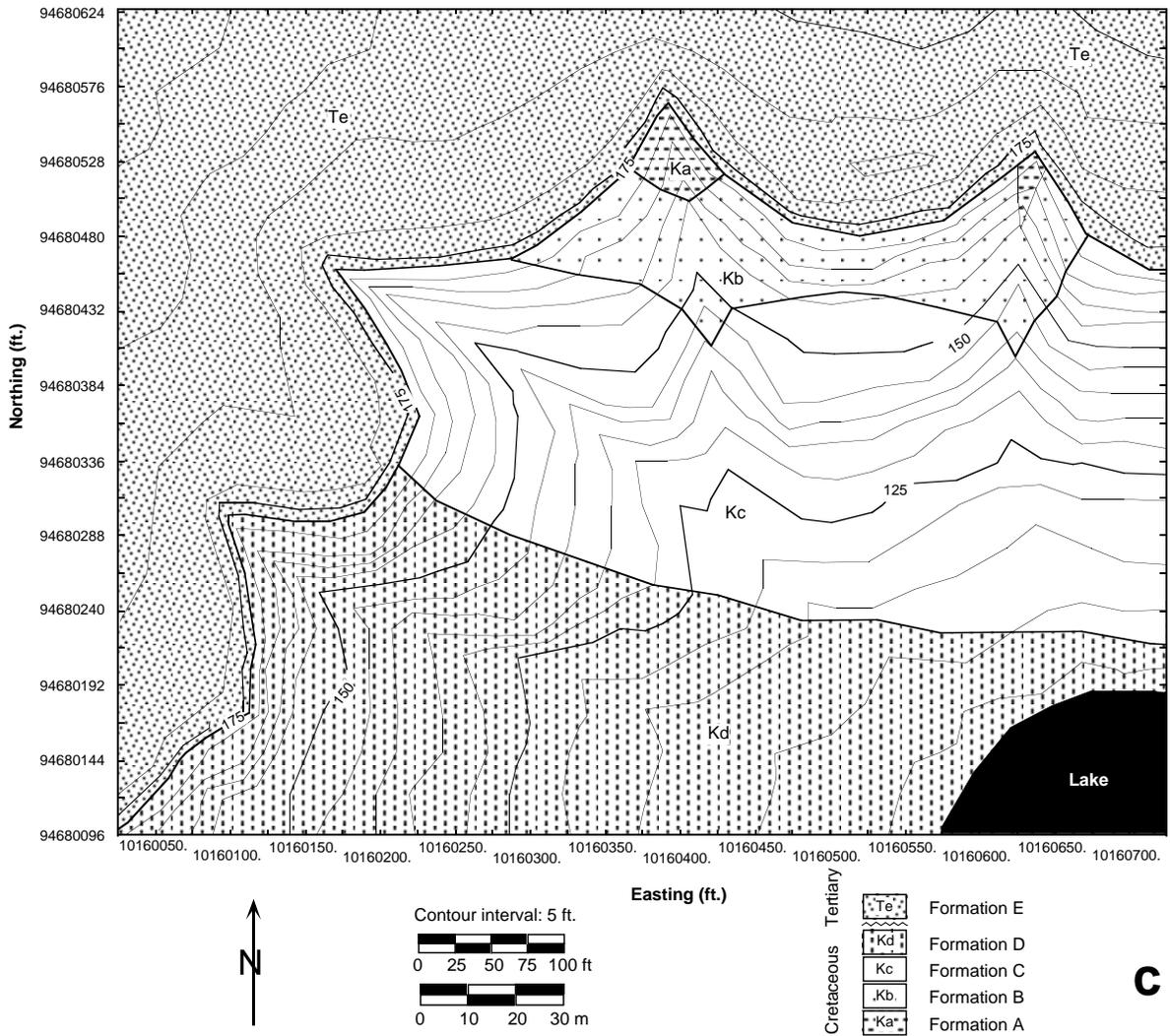| Kb | Formation B
| Ka | Formation A

C

Figure 4, continued: (c) Final topographic/geologic map prepared using CANVAS: contour lines were corrected; the polygon tool was used to "connect the dots" of stations located along contacts and to show the areal extent of the five formations; a scale and legend were added.

Three Dimensional View of the Sayreville Pit, Sayreville, Middlesex County, New Jersey

by Phillip J. Martell
October 1995

● = Study Area

4479190.00

0555120.00

165 meters

220 meters

No Data

12°

N
MN

0554950.00   4779400.00

V.E. = 20x

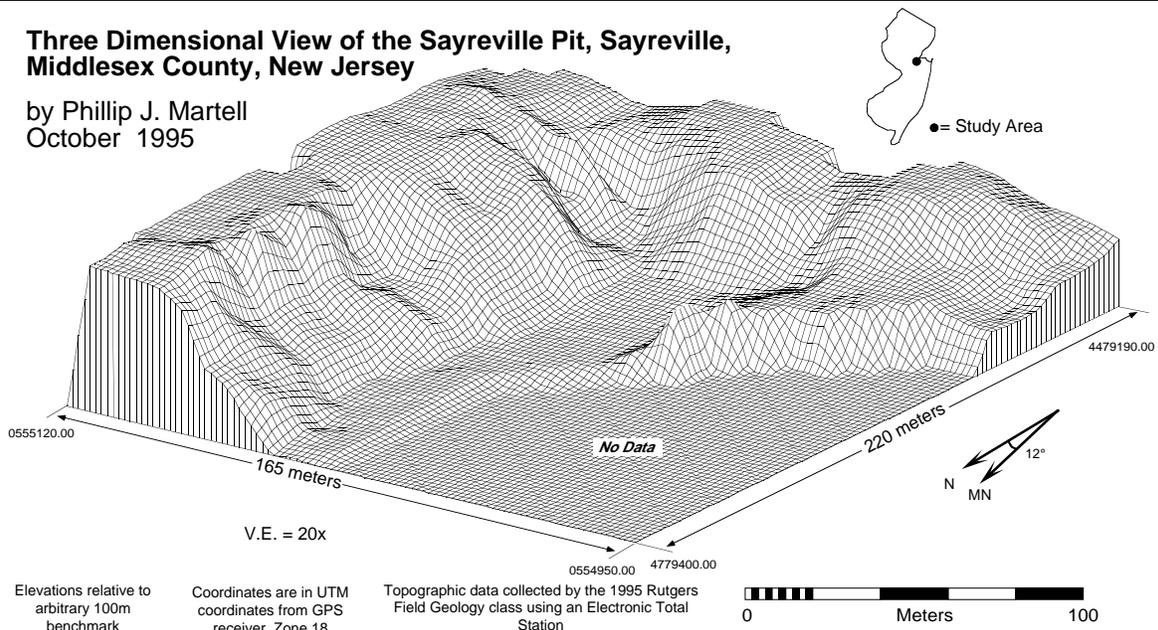| Elevations relative to arbitrary 100m benchmark | Coordinates are in UTM coordinates from GPS receiver, Zone 18 | Topographic data collected by the 1995 Rutgers Field Geology class using an Electronic Total Station |

0   Meters   100

Figure 5: Three-dimensional perspective (fishnet) diagram illustrating the topography of the southeast wall of the Sayreville Pit. Topographic data were collected using an ETS and were plotted by Phillip Martell using SURFACE and CANVAS. Martell's original diagram has been altered slightly to conform to publication requirements.
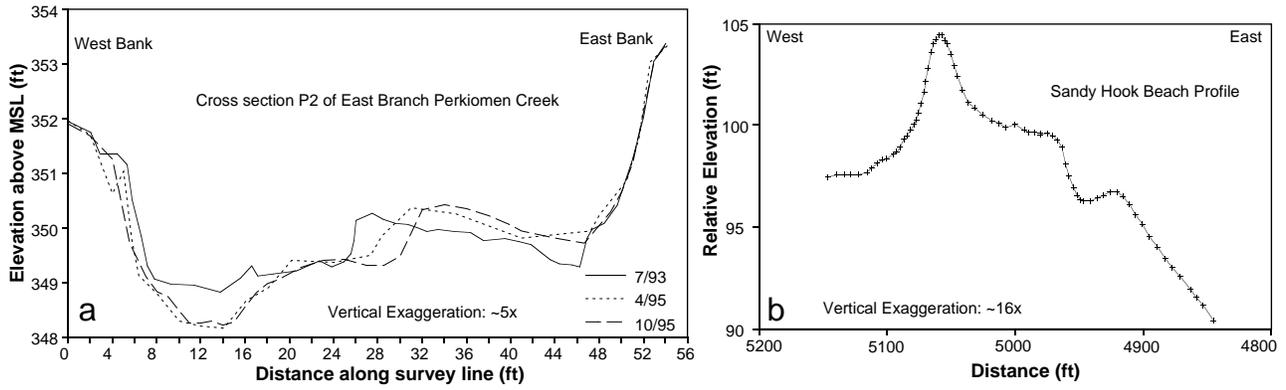
Figure 6: Examples of topographic profiles plotted using CRICKETGRAPH. (a) Topographic profiles measured with an automatic level at East Branch Perkiomen Creek for three survey periods; note the change in channel geometry through time. (b) Topographic profile across the dune and beach face at Sandy Hook, New Jersey, measured with an ETS during a field trip for the Sedimentology class. A plot similar to this was prepared on a portable computer and shown to the class while the students were still in the field.