

Introduction

These exercises will emphasize practical mapping skills: reading maps and collecting data with the Brunton compass. Though it is not particularly difficult to locate yourself on a campus map or take a strike and dip on a cardboard plane, we will emphasize some procedural skills that will help us when we go into the field. Through the semester you will find that particular fundamental exercises and concepts will recur. Don't fret. This is no accident, as geologic mapping is most productive and enjoyable when your fundamental skills are tight. We will practice over and over so that when we are in the field, instead of investing energy in data collection, you can focus your energy on interpreting the data you just collected. This is how we will learn to make great maps.

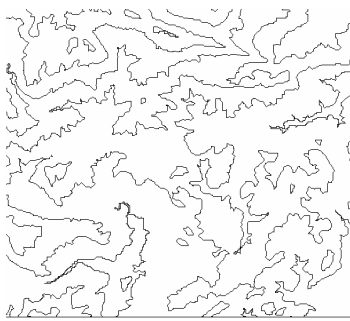
Materials

Brunton Compass	C-Thru Protractor Ruler	Map of exercise area
Index of structural symbols	Clipboard	Pencils and erasers
Laser rangefinder or long tape	Good Strike/Dip surfaces	

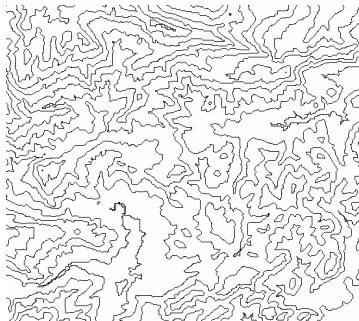
Working With Maps

- **Orienting the Map:** No matter which direction you are looking, you will always rotate the map until it is appropriately oriented so that the map's north arrow is pointing north. You can confirm your orientation with your compass. This assures that when you are rapidly glancing between the map and the landscape, the features are in their appropriate location. We must try overcome the tendency to believe that 'north is up' and recognize that the map is a dynamic visualization and data collection tool, not an image hung appropriately on the wall.
- **Distance and Elevation Approximation:** This skill will help you to make rough measurements and aid in finding yourself on the map. We will work to calibrate our eyes to measure distance, not just horizontally but along an incline as well. An even more difficult skill will be calibrating our eyes to measure differences in elevation. During the lab, we will use a laser rangefinder to confirm/dispel our approximations.
- **Contours and Map Scale:** Maps come in different scales and with different contour intervals. When we work with paper maps, the scale and contour interval are constant and our perceptions of distance and elevation become tuned to the map we are working with. We become comfortable translating back and forth between observations in the real world and plotting them on the map. When working with digital mapping tools, we can zoom in and out on our maps and display contours at variable intervals. This complicates our usage of maps and emphasizes the need for careful observation of topography to locate not only our position but also the relative scale of the map in our viewer.

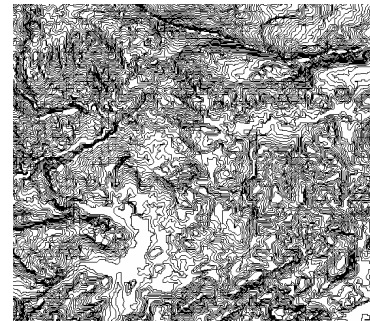
Same Map Scale, Various Contour Intervals



100m interval

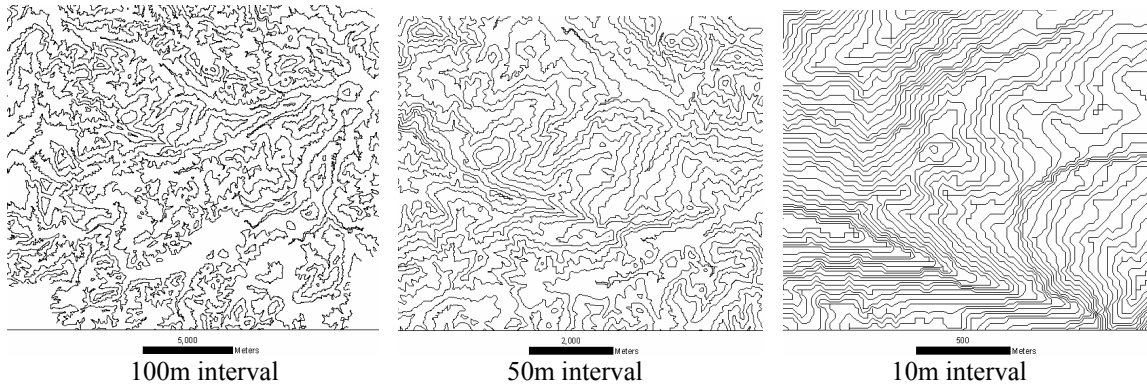


50m interval



10m interval

Different Map Scale, Various Contour Intervals, Same Contour Density



The Brunton Compass

- **Declination:** Magnetic North (where your compass points toward) is offset from True North (our axis of rotation). Depending on where on the earth you are, the declination could be slightly east or west of True North. All good maps will state the declination in your particular location. You will use this value to correct your compass so that when the compass is directed at True North, the compass will read 0 degrees. Be certain to check that your declination is correct as mistakes will lead to great confusion regarding all the data you collect.
- **Local Magnetic Interference:** Nearby metal items and electric fields can significantly interfere with your compass readings. To help this, make measurements at a distance from belt buckles and hammers and when in urban environments, be wary of induced magnetic fields due to motors or spinning metal objects. (MIT's campus is full of magnetic interference: pipes, pumps, etc.)
- **Taking a Bearing:** This technique will help you measure the bearing to a distant object.
 1. hold the compass in two hands: one on the body, one on the mirror.
 2. hold the compass down by your belly (beware of the belt buckle...) so you look down into it.
 3. level the compass so that the bubble is in the round bull's eye
 4. using the mirror-holding hand, tilt the mirror until you see the object of interest.
 5. using the fingers of the hand holding the body of the compass, tilt up the black arm so that you can see it in the mirror. check that the top-tip of the arm is lined up with the line on the mirror's face.
 6. when you have the bubble in the bull's eye, you can see your object in the mirror (aligned with the line and the arm), you are ready to read the number pointed at by the north arrow. This is the bearing to your object of interest.
- **Triangulation:** This techniques will help you calculate your approximate position in the field.
 1. Locate three distinct landmarks that you can see from where you are standing and locate exactly (or to very high precision) on the map.
 2. Take the bearing to each of those three landmarks, reading the value next to the SOUTH arrow so that you know the bearing from the landmark to yourself.
 3. On the map, use your protractor ruler to draw a line through the landmark, with your measured bearing. Do this for three or more landmarks and they will cross at your approximate location.

Structural Data Collection in the Field

- **Planar Data:**
 - **Strike and Dip:**
 - We measure strike and dip to know the geometric orientation of a planar geologic feature such as sedimentary beds or faults. The ‘strike’ is the directional bearing of a horizontal line tracing across the planar surface (like the line made by the water’s edge on a boat-ramp). According to the ‘right-hand-rule,’ we measure the strike in the direction so that the down-dip direction is on the right side of the compass. This convention prevents us from drawing the dip direction on the wrong side of the strike line. The ‘dip’ is the number of degrees below horizontal, [$0^{\circ} - 90^{\circ}$], that the surface is (e.g. an almost flat surface has a low dip and a steep surface has a high dip). As there are multiple types of planar features in rocks (including: fractures, joints, faults, foliation, cleavage, bedding, etc.) we must make note of exactly what kind of feature we are measuring. As well, geologic planar features are seldom perfectly flat so our measurement procedure must also reflect this. We can either measure non-flat planar features by taking one measurement that we believe to average out the variability or we can take multiple measurements at different points along the planar feature (e.g. if you suspect that the bed might be folded, collect multiple measurements for plotting on a stereo-net.) Also, if working with sedimentary beds, confirm if the bed is right-side-up or if it is overturned. Here is the plan:
 1. Locate the surface of interest. Check for up indicators, and for how variable the planar surface is. Pick a method and location for measurement that reflects the preceding observations.
 - If you find a local point that is reflective of the average surface and you want to measure there, place your field book or clipboard on the surface and make the measurement on that surface.
 - If you cannot confidently pick a point to make the measurement, position yourself so that you are staring directly along the perceived average strike of the bed. Use your compass and the “taking a bearing” technique to measure the bearing along the strike line.
 2. Measure the strike remembering to follow the “Right-Hand-Rule.” Our compasses are $0^{\circ} - 360^{\circ}$ or ‘azimuth’ compasses. (The other kind of compasses are ‘quadrant’ compasses and are divided into 4 distinct $0^{\circ} - 90^{\circ}$ quadrants.) When we take measurements of strike, we always want the black arm of our compass pointing in a direction so that the right side of the compass is on the down-dip side.
 3. Rotate your compass so that it is standing on its side, on the planar surface. Measure the dip so that the compass is aligned perpendicular to the strike direction and along the steepest line of descent (this is the direction that dribbled water would flow down-slope). Using the inclinometer (which you control using the lever-arm on the bottom of your compass) measure dip by adjusting the arm until the bubble is in the center of the inclinometer tube. A good check that you are measuring the true dip is that if you rotate the compass in different dip-directions, the bubble will only move to one side of the bubble-tube. If it moves to both sides, there is a steeped dip to be measured.
 4. We report data as (strike/dip) or (245/32)

Structural Data Collection in the Field (ctd.)

- **Linear Data**
 - Measuring the **Trend and Plunge** of a linear feature such as a fold axis or a stretching lineation in a sheared conglomerate combines the techniques discussed earlier.
 1. First approximate the trend and plunge with a non-magnetic linear object (such as a pencil). You make the measurements off this approximation.
 2. Measure the bearing of the pencil in the down-plunge direction. This is the convention and must be followed.
 3. The plunge can be measured directly off the pencil using the inclinometer or can be approximated by standing perpendicular to the plunge direction and holding the compass up and visually aligning it along the plunging feature.
 4. We report the data following the convention (plunge→trend) or (35→342) read as “plunging 35 degrees toward 342°.”

Structural Data Analysis in the Field

- **Plotting your data:** Right after making a measurement, write it down...don't hesitate as it is easy to forget. After it is written down, locate your position on the map and plot the data there so that you can see your new data in context of the map and the other data you have collected.
 - Symbols for plotting structural data: Keep them small enough that they won't interfere with plotting subsequent data, but large enough that they can be read clearly.
 - Strike/Dip is a line drawn with the orientation of the strike and a short line perpendicular to the strike line (remembering the right hand rule) showing the dip direction. Write the value of the dip near the short line.
 - Trend and plunge are drawn by drawing an arrow in the direction of the measured trend. The value of the plunge is written near the tip of the arrow.
 - Plotting the data using a 'C-thru' ruler/protractor
 - Using a north-south trending line for reference, measure the angle of the strike or the trend you collected. Draw the symbol centered directly over where you collected it. Remember that Azimuth is measured 0° – 360° in the clockwise direction starting at True North.
 - Do you see any trends in the data you are collecting? Do the strikes and dips show a regionally uniform trend or do they reflect some systematic structural deformation or is the data all over the place and can't be interpreted with the data you currently have...where will you go next to improve your understanding?
 - Structural data we collect in the field is imprecise...but how much variability can we attribute to our measurement techniques and how much is due to the geologic variability itself? How could we test this?

APPENDIX 7: Symbols for Geologic Maps

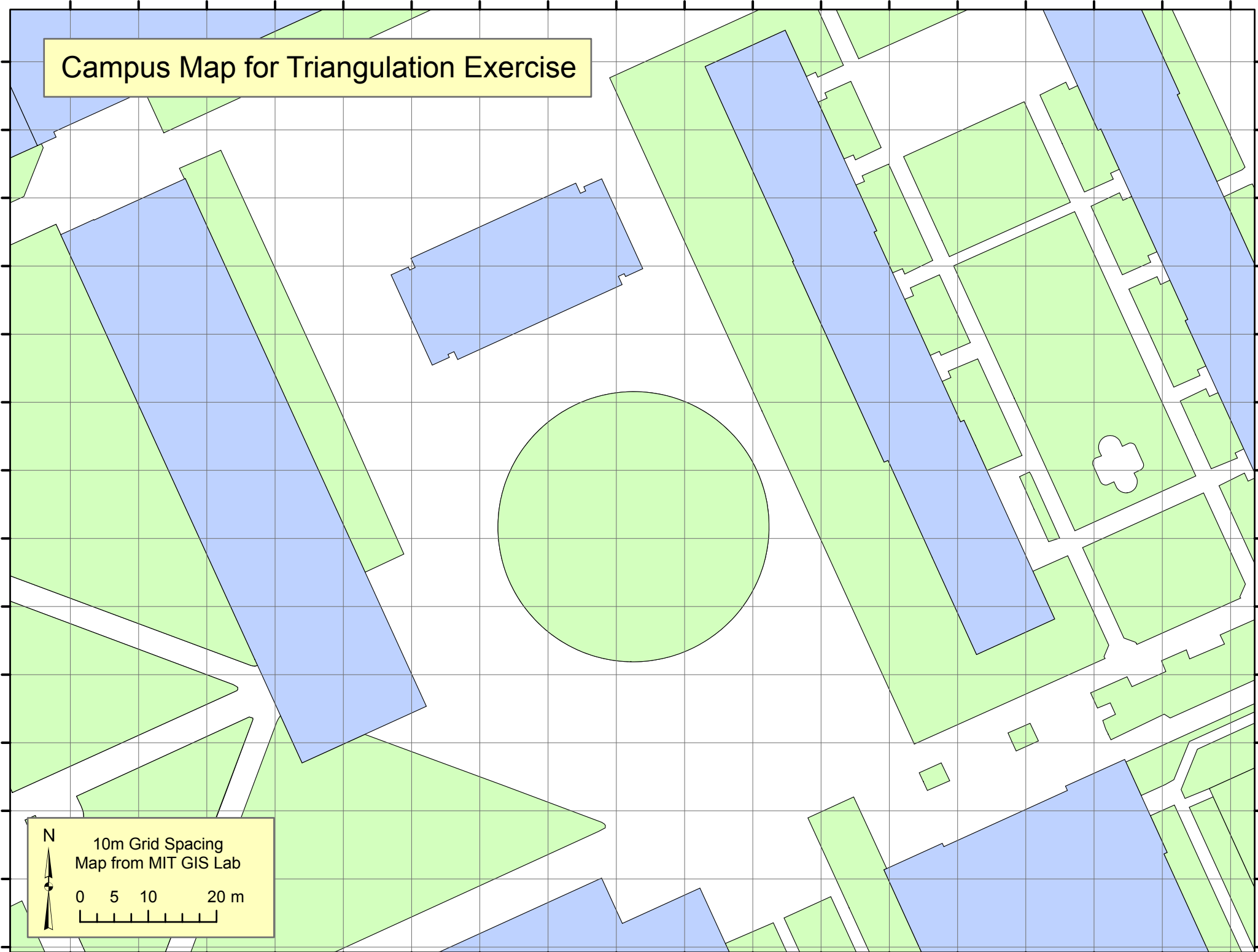
- 1 Contact, showing dip where trace is horizontal, and strike and dip where trace is inclined
- 2 Contact, located approximately (give limits)
- 3 Contact, located very approximately, or conjectural
- 4 Contact, concealed beneath mapped units
- 5 Contact, gradational (optional symbols)
- 6 Fault, nonspecific, well located (optional symbols)
- 7 Fault, nonspecific, located approximately
- 8 Fault, nonspecific, assumed (existence uncertain)
- 9 Fault, concealed beneath mapped units
- 10 Fault, high-angle, showing dip (left) and approximate dips
- 11 Fault, low-angle, showing approximate dip and strike and dip
- 12 Fault, high-angle normal (D or ball and bar on downthrown side)
- 13 Fault, reverse (R on upthrown side)
- 14 Fault, high-angle strike-slip (example is left lateral)
- 15 Fault, thrust (T on overthrust side)
- 16 Fault, low-angle normal or detachment (D on downthrown side)
- 17 Fault, low-angle strike-slip (example is right lateral)
- 18 Fault, low-angle, overturned (teeth in direction of dip)
- 19 Optional sets of symbols for different age-groups of faults
- 20 Fault zone or shear zone, width to scale (dip and other accessory symbols may be added)
- 21 Faults with arrows showing plunge of rolls, grooves or slickensides
- 22 Fault showing bearing and plunge of net slip
- 23 Point of inflection (bar) on a high-angle fault
- 24 Points of inflection on a strike-slip fault passing into a thrust

- 25 Fault intruded by a dike
- 26 Faults associated with veins
- 27 Anticline, showing trace and plunge of hinge or crest line (specify)
- 28 Syncline (as above), showing dip of axial surface or trough surface
- 29 Folds (as above), located approximately
- 30 Folds, conjectural
- 31 Folds beneath mapped units
- 32 Asymmetric folds with steeper limbs dipping north (optional symbols)
- 33 Anticline (top) and syncline, overturned
- 34 Antiformal (inverted) syncline
- 35 Synformal (inverted) anticline
- 36 Antiform (top) and synform (stratigraphic sequence unknown)
- 37 Separate dome (left) and basin
- 38 Culmination (left) and depression
- 39 Small anticline and syncline, showing shapes in horizontal section
- 40 Vertically plunging anticline and syncline
- 41 Monocline, south-facing, showing traces of axial surfaces
- 42 Steeply plunging monocline or flexure, showing trace in horizontal section and plunge of hinges
- 43 Plunge of hinge lines of small folds, showing shapes in horizontal section
- 44 Strike and dip of beds or bedding
- 45 Strike and dip of overturned beds
- 46 Strike and dip of beds where stratigraphic tops are known from primary features
- 47 Strike and dip of vertical beds or bedding (dot is on side known to be stratigraphically the top)
- 48 Horizontal beds or bedding (as above)

- 49 Approximate (typically estimated) strike and dip of beds
- 50 Strike of beds exact but dip approximate
- 51 Trace of single bed, showing dip where trace is horizontal and where it is inclined
- 52 Strike and dip of foliation (optional symbols)
- 53 Strike of vertical foliation
- 54 Horizontal foliation
- 55 Strike and dip of bedding and parallel foliation
- 56 Strike and dip of joints (left) and dikes (optional symbols)
- 57 Vertical joints (left) and dikes
- 58 Horizontal joints (left) and dikes
- 59 Strike and dip of veins (optional symbols)
- 60 Vertical veins
- 61 Horizontal veins
- 62 Bearing (trend) and plunge of lineation
- 63 Vertical and horizontal lineations
- 64 Bearing and plunge of cleavage-bedding intersection
- 65 Bearing and plunge of cleavage-cleavage intersections
- 66 Bearings of pebble, mineral, etc. lineations
- 67 Bearing of lineations in plane of foliation
- 68 Horizontal lineation in plane of foliation
- 69 Vertical lineation in plane of vertical foliation
- 70 Bearing of current from primary features; from upper left: general; from cross-bedding; from flute casts; from imbrication

- 71 Bearing of wind direction from dune forms (left) and cross-bedding
- 72 Bearing of ice flow from striations (left) and orientation of striations
- 73 Bearing of ice flow from drumlins
- 74 Bearing of ice flow from crag and tail forms
- 75 Spring
- 76 Thermal spring
- 77 Mineral spring
- 78 Asphaltic deposit
- 79 Bituminous deposit
- 80 Sand, gravel, clay, or placer pit
- 81 Mine, quarry, or open pit
- 82 Shafts: vertical, inclined, and abandoned
- 83 Adit, open (left) and inaccessible
- 84 Trench (left) and prospect
- 85 Water wells: flowing, nonflowing, and dry
- 86 Oil well (left) and gas well
- 87 Well drilled for oil or gas, dry
- 88 Wells with shows of oil (left) and gas
- 89 Oil or gas well, abandoned (left) and shut in
- 90 Drilling well or well location
- 91 Glory hole, open pit, or quarry, to scale
- 92 Dump or fill, to scale

Campus Map for Triangulation Exercise



10m Grid Spacing
Map from MIT GIS Lab

