COMPASS & MAP NAVIGATION

AHS Presentation

March 30, 2022

Prepared by: Raffi Avedian

ARMENIAN HIKING SOCIETY

PRESENTATION FORMAT

- The presentation is approximately 45 minutes long
- Please keep your suggestions and comments until presentation is complete. There will be opportunity to hear your questions and comments at the end of the presentation
- All constructive comments and suggestions will be incorporated into these slides and will be made available to everyone to download from AHS website: https://ahshiking.com

OBJECTIVE

- Ability to navigate in wilderness is one of the most important skills any outdoor enthusiast must possess. GPS and Cell phones are great navigation tools until they stop working (damaged, dead batteries)
- Having the skills to navigate without relying on technology is one of the necessities of outdoor survival
- My goal today is to convey and share enough information about navigation using a **map and a compass** to inspire you to learn more and practice this life saving skill in wilderness to find your way home without relying on technology

PRESENTATION CONTENT

The presentation is in two (2) parts as follows:

Part 1: Maps

We will learn the basics of reading a topo map and be able to identify peaks and valleys

Part 2: Navigation using Compass and Map

We will learn the basic skills necessary to navigate using compass and a map

Let’s get familiar with some terminology

COMPASS NAVIGATION GLOSSARY OF TERMS

Term	Explanation
True North	True north is the direction that points directly towards the geographic North Pole. This is a fixed point on the Earth's globe
Magnetic North	Magnetic north is the direction that a compass needle points to as it aligns with the Earth's magnetic field
Grid North	Because topo maps are flat and the Earth is spherical, cartographers must make slight variations to compensate for the curvature of the Earth's surface. As a result, the grid lines on your map point ever so slightly wide of True North
Heading or Azimuth	Direction of travel
Bearing	A "bearing" is simply a precise way to describe a direction. For example, instead of heading "southeast" to get to Glendale, you might follow a bearing of 120 degrees ☺
Triangulation	Is a technique to locate your position on a map. If you are lost, knowing which direction North is, isn't enough–you must also find your own position on the map

COMPASS NAVIGATION GLOSSARY OF TERMS

Term	Explanation
Magnetic Declination	At most places on the Earth's surface, the compass doesn't point exactly toward geographic (true) north. **The deviation of the compass from true north** is an angle called "**declination**" (or "magnetic declination")
Landmark	Is an object or feature of a landscape or town that is easily seen and recognized from a distance: Peaks, lakes, man made structures, etc.
Orienting Arrow	Large **RED** arrow. Used to orient the bezel. It has an outline shaped to exactly fit the magnetized end of the needle
Orienting Lines / Meridian Lines	Parallel lines that rotate with the bezel; correctly aligning these with the north-south lines on a map aligns your orienting arrow with north
Index Pointer	Back end of the direction-of-travel arrow; ends at the edge of the dial and is where you take degree readings
Red in the shed	Means rotate the bezel until the magnetized needle is inside the orienting arrow

FEW FACTS

Magnetic compasses are unreliable in polar regions (at very high latitudes, a magnetic compass can even point south)

All maps point to the **true north**, but your compass needle always points to the **magnetic north**

You can use a bearing to get to a location any time **you know where you** are on a map

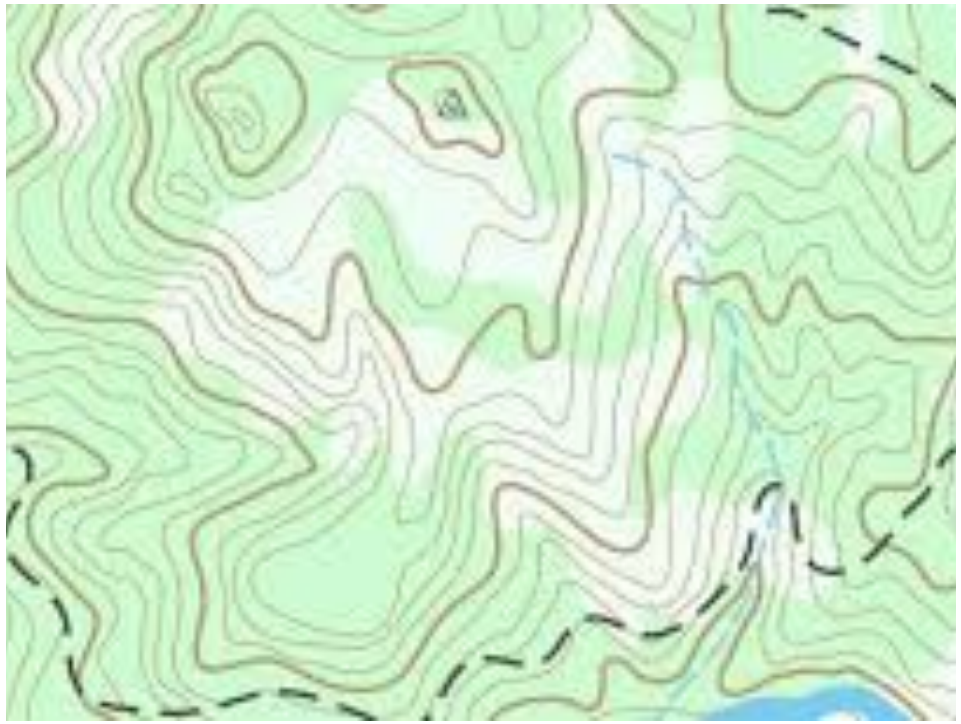
Understanding Maps

INTERESTING FACTS

- **Fact**: Search and Rescue (SAR) teams are regularly sent out to find hikers that became lost on familiar trails
- **Fact**: Something as simple as a downed tree that forces you off the trail, can result in your inability to find the trail again and leave you a bit lost throughout a cold and wet night until a SAR unit finds you the next day
- **Fact**: Statistics show that vast majority of SAR searches are for day hikers only a few miles from their car
- **Fact**: Half the rescues are for experienced hikers in areas they know well (or so they thought)

While navigating, keep track of where you on a map at all times

WHAT TYPE OF MAP?



Topographic maps are ideal for wilderness navigation

- The topographic map is a two-dimensional representation of the Earth's three-dimensional landscape
- It is a detailed and accurate illustration of man-made and natural features on the ground such as roads, railways, power transmission lines, contours, elevations, rivers, lakes and geographical names
- **For this presentation, we will focus on using topo maps**

HOW TO READ A TOPO MAP

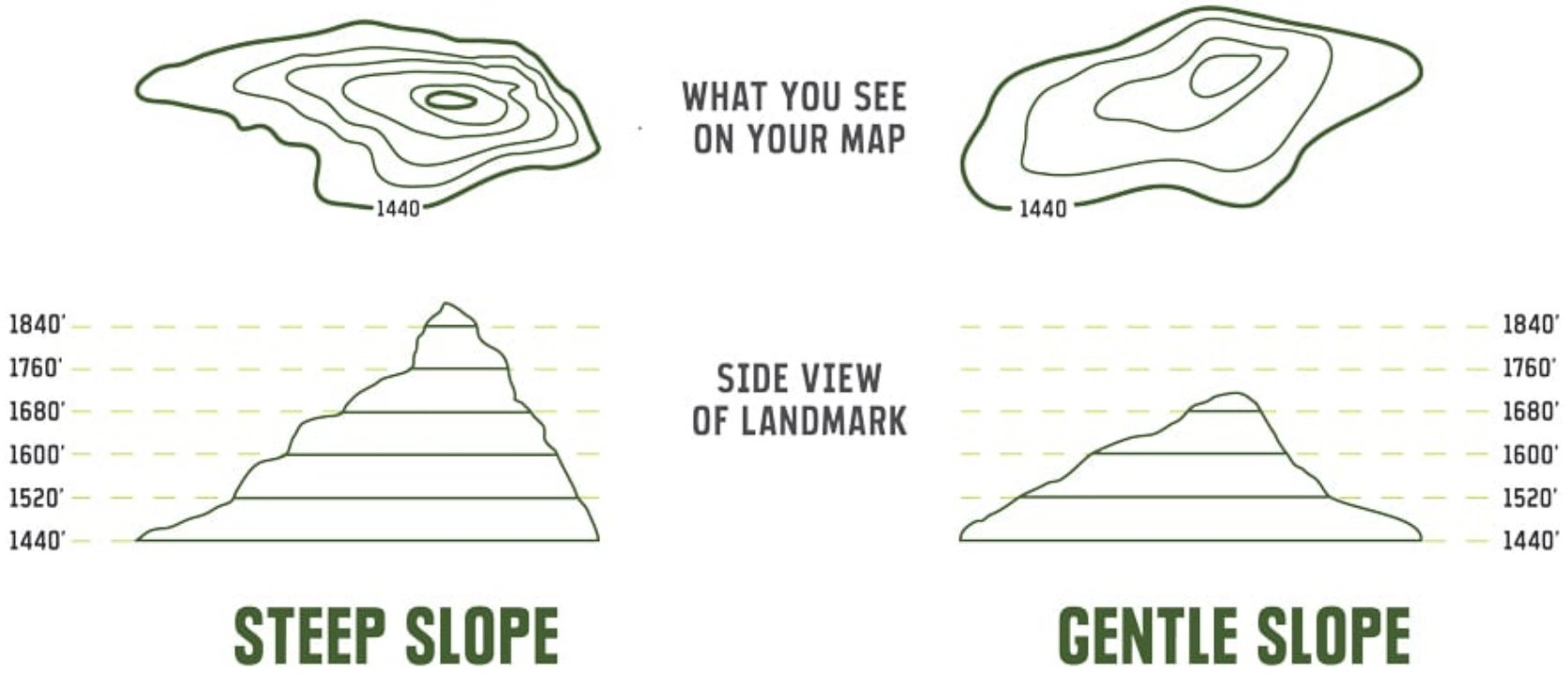
A topo map shows not only location of things (roads, trails, structures, etc.), it also helps you visualize what the terrain looks like. This is made possible by its unique characteristics:

1. **Contours**
2. **Scale**
3. **Legend**

UNDERSTANDING CONTOURS

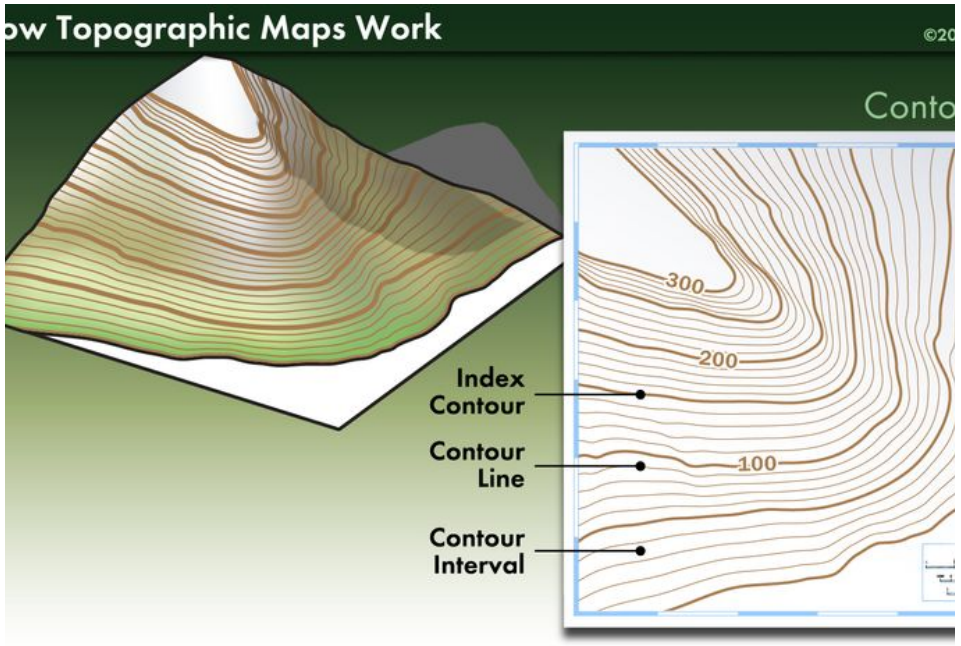
Contours are imaginary lines that join points of equal elevation

Contours make it possible to measure the height of mountains, depths of the ocean bottom, and steepness of slopes



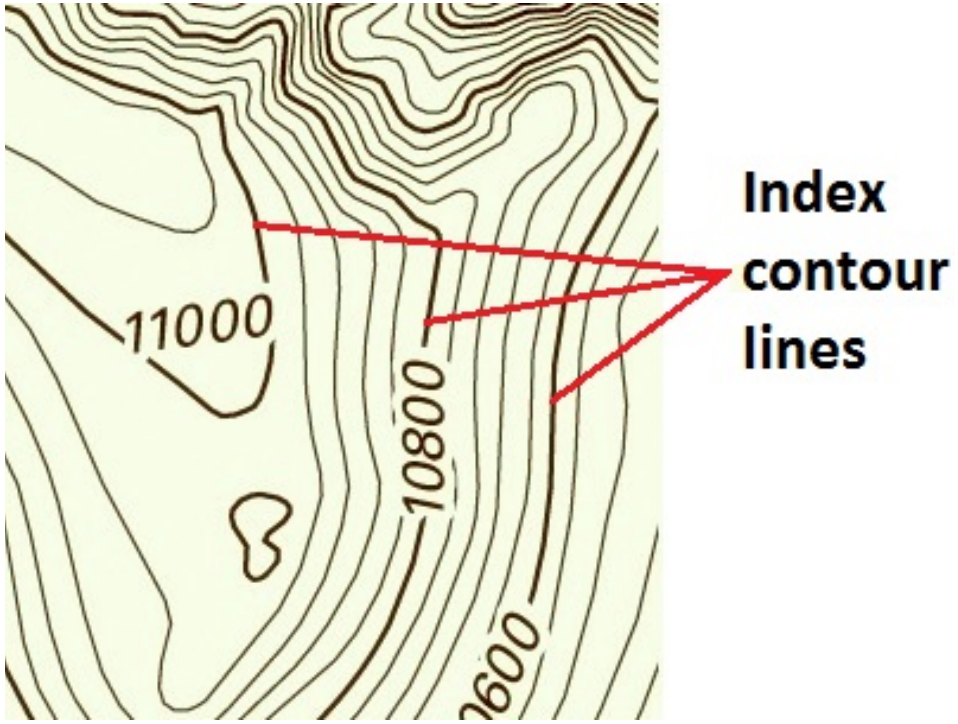
UNDERSTANDING CONTOURS …

- **Contour interval:** The change in elevation from one contour line to the next is always the same within the same map
- Many maps have either a 40- or 80-foot contour interval: An 80-foot interval simply means that each contour line is 80 vertical feet away from the next closest line
- You can find the contour interval map legend



UNDERSTANDING CONTOURS …

- **Contour Index Lines**: Topographic maps give you the power to visualize three-dimensional terrain from a flat piece of paper. The feature that makes this possible is contour index lines. Every fifth contour line is a thicker, “index” line
- Elevations are marked on the index contour lines only
- If the numbers associated with specific contour lines are increasing, the elevation of the terrain is also increasing. If the numbers associated with the contour lines are decreasing, there is a decrease in elevation

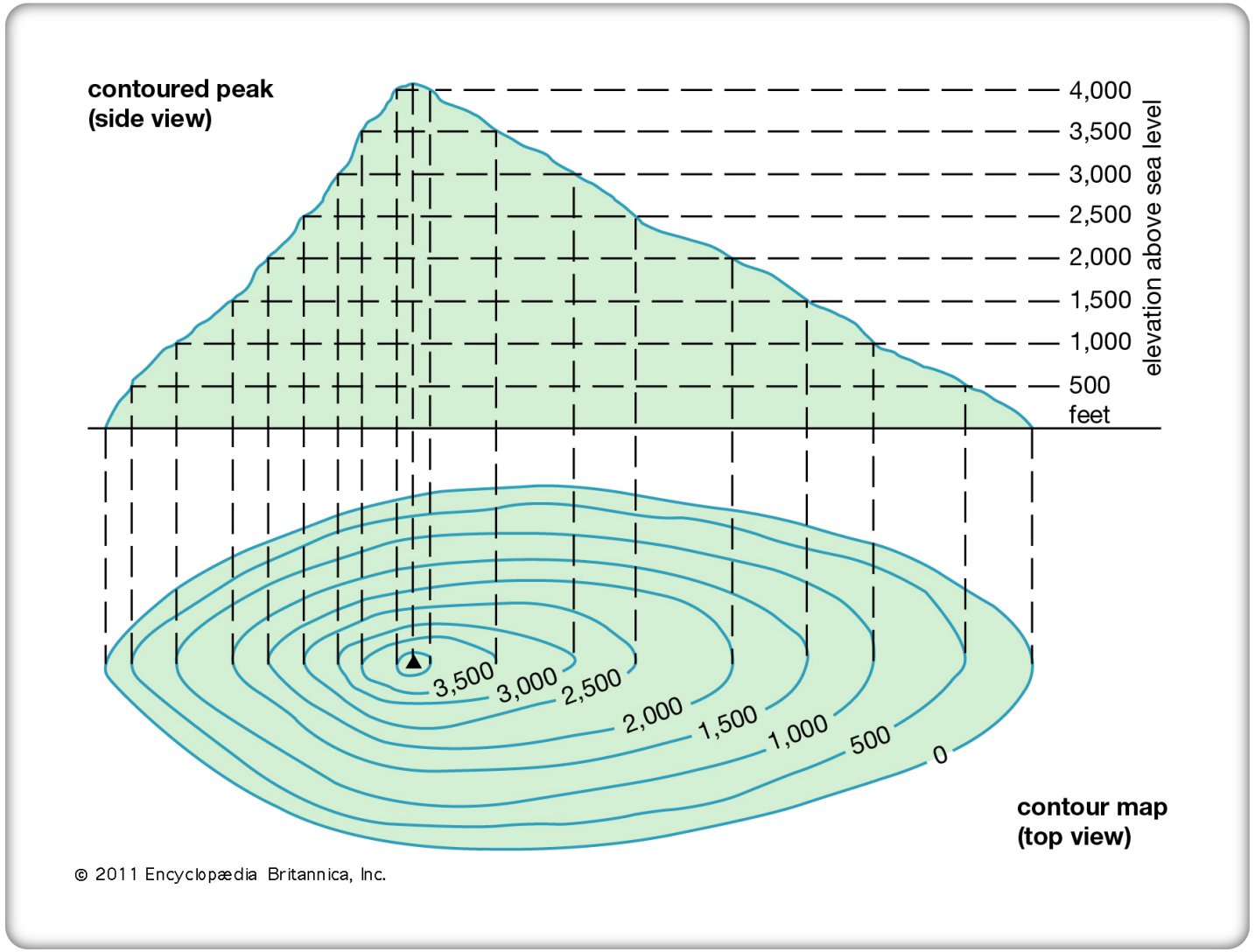


CONTOURS DISSECTED

Let’s examine how contour lines represent ground elevations, depressions and slopes

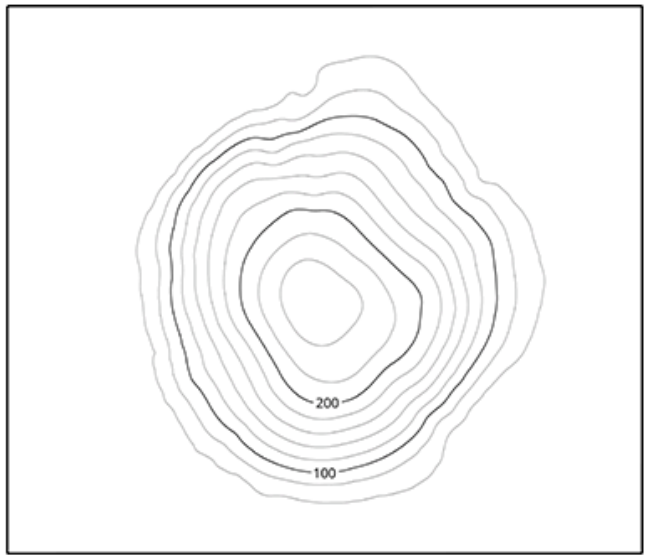
CONTOUR IN 3-D

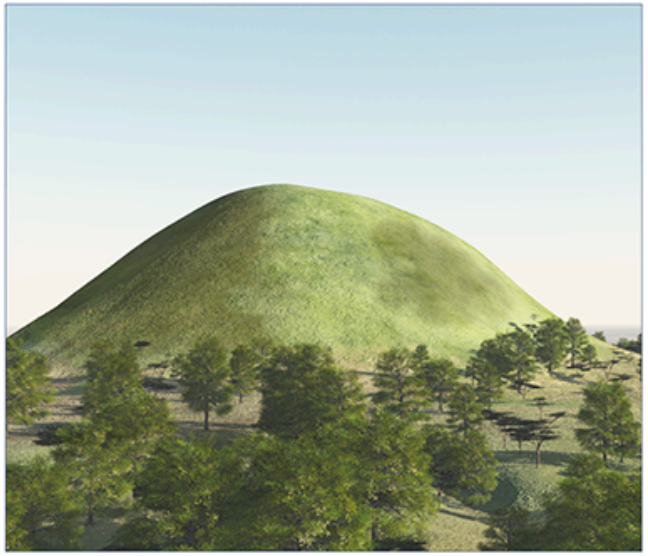
Note the contour index lines showing elevation changes



HILLS, PEAKS, KNOLLS, MOUNTAINS

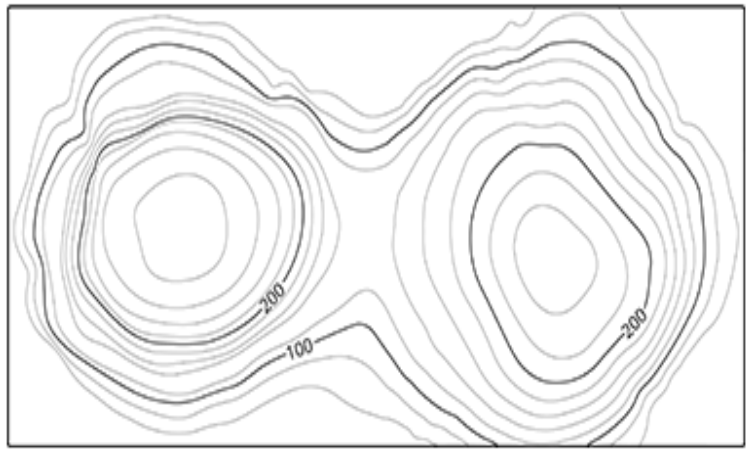
A hill, peak, knoll or mountain is an area of high ground. From a hilltop, the ground slopes down in all directions. A hill is shown on a map by contour lines forming concentric circles. The inside of the smallest closed circle is the hilltop.

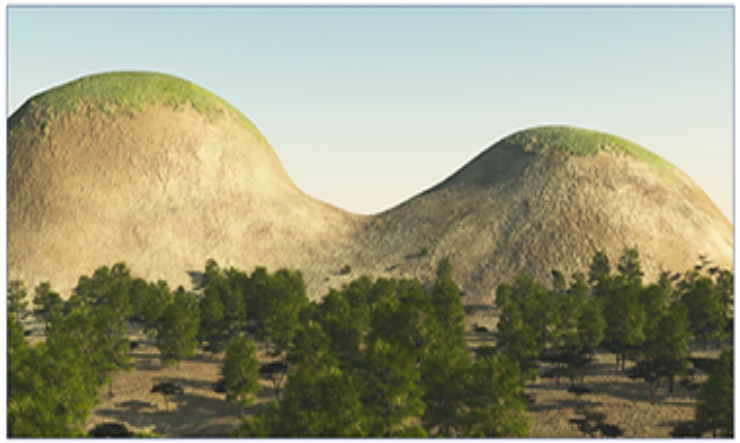




SADDLE

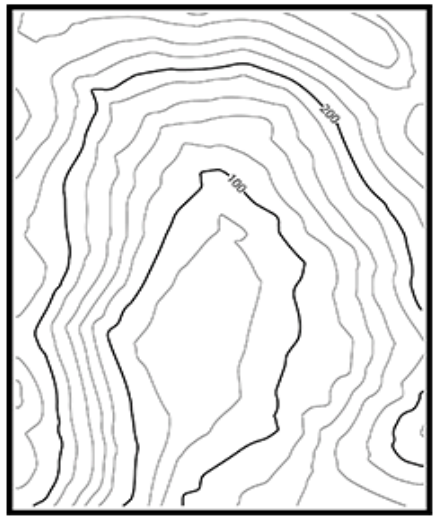
A saddle is a dip or low point between two areas of higher ground. When standing in a saddle, there is high ground in two opposite directions and lower ground in the other two directions. A saddle typically looks like an hourglass.





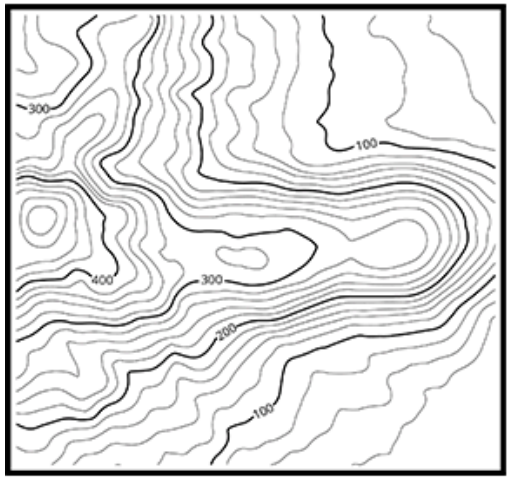
GULLY

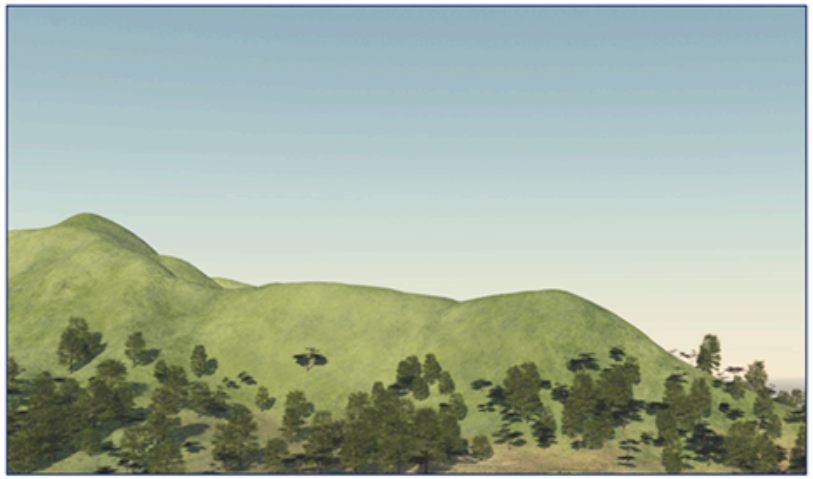
A gully is a stretched-out groove in the land, usually formed by a watercourse/stream, and has high ground on three sides. Depending on its size and location water sometimes flows through it, from high to low. Contour lines forming a gully are either U-shaped or V-shaped.



RIDGE

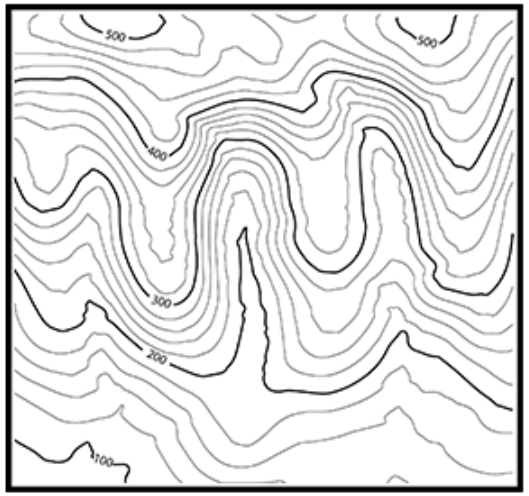
Is depicted as two contour lines (often of the same contour) running side by side at the same elevation for some distance. When the lines diverge, the ridge is either flattening out to a high plateau or continues to rise with additional contour lines.

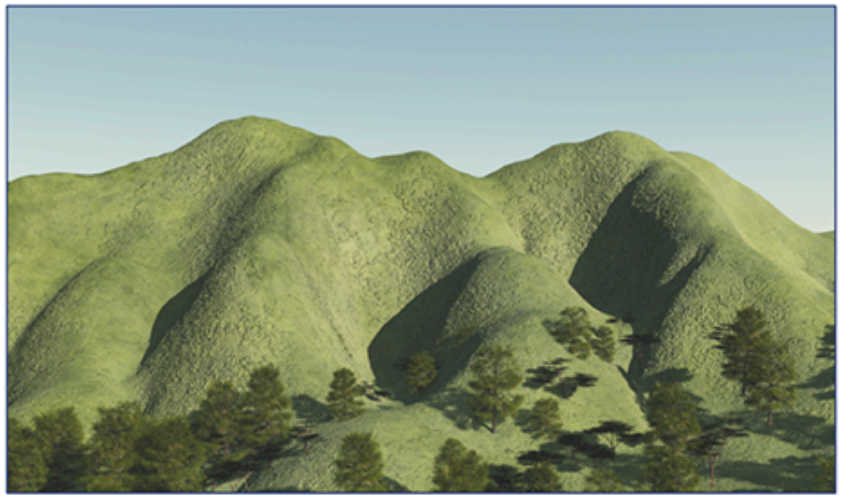




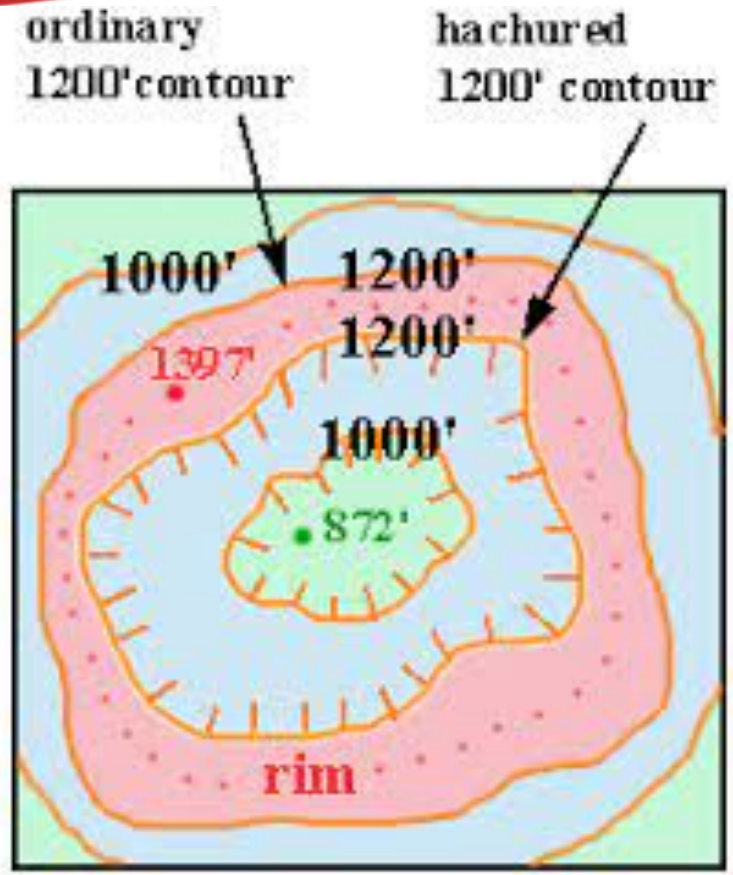
SPUR

A spur is a short, continuous sloping line of higher ground, normally extending out from the side of a ridge. A spur is often formed by two roughly parallel streams cutting draws down the side of a ridge. The ground will slope down in three directions and up in one. Contour lines on a map depict a spur with the U or V pointing away from high ground.

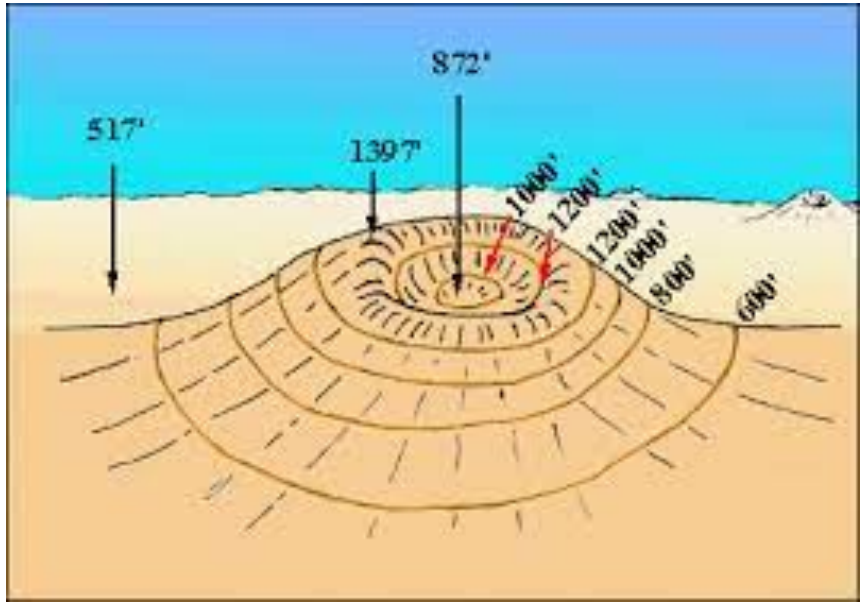


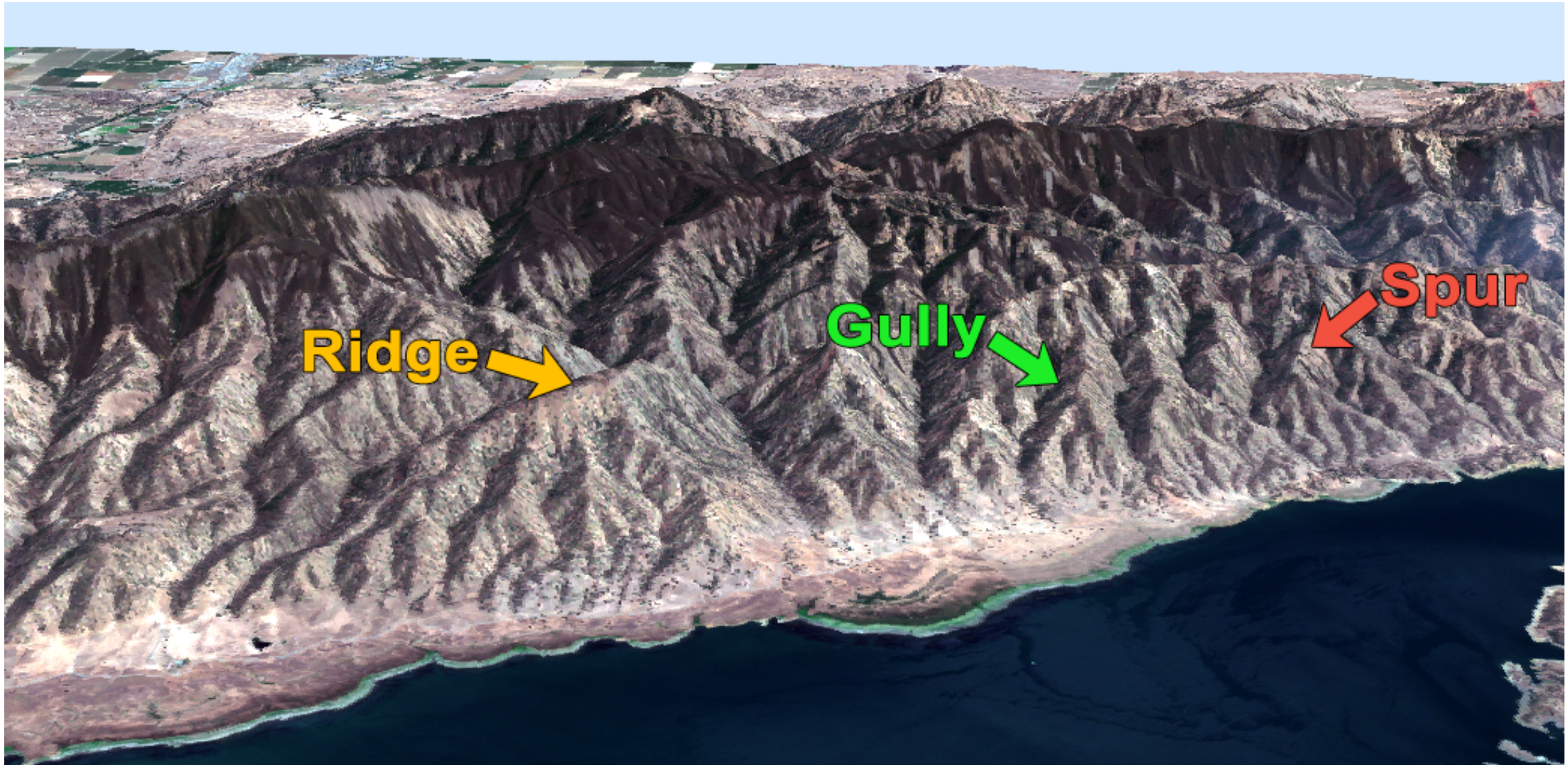


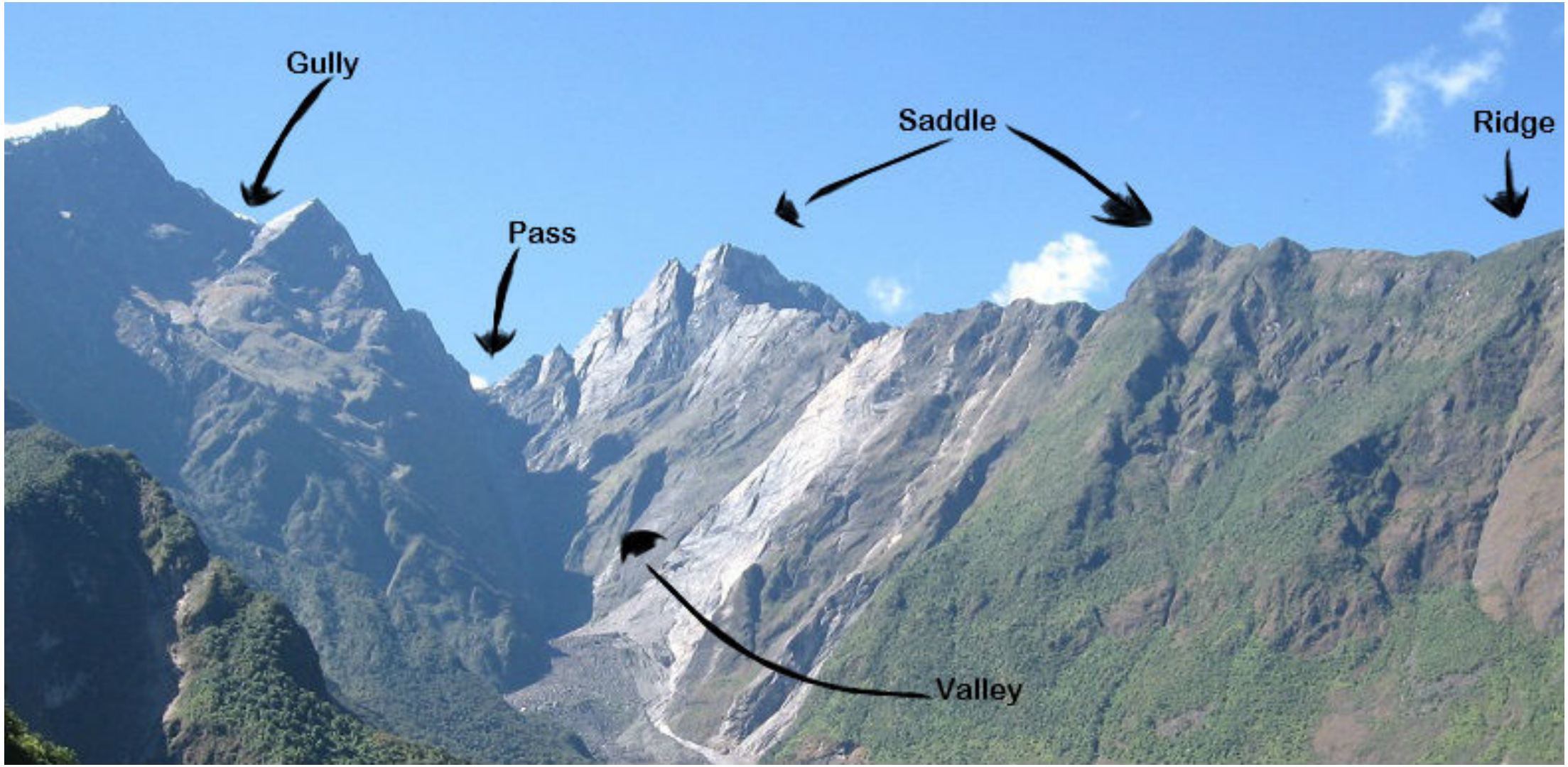
DEPRESSION



- **Contour** lines that show a **depression**, crater, or sinkhole on a map are represented by dashed (hachured) lines on the inside of a **contour** line




Ridge
Gully
Spur


Gully
Saddle
Ridge
Pass
Valley

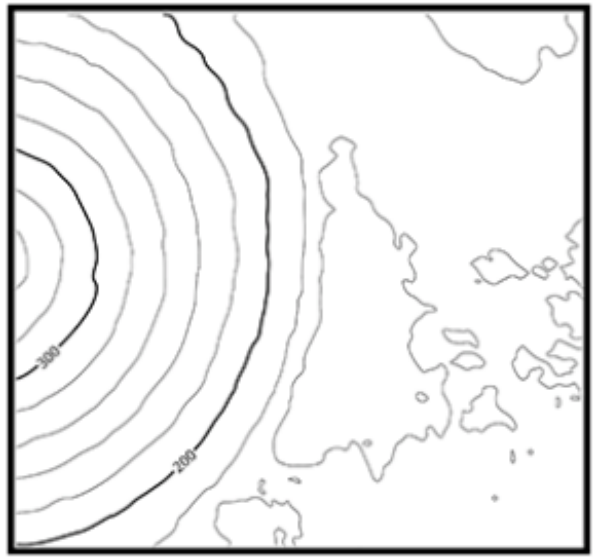
SLOPE

The rate of rise or fall of a terrain feature is known as its **slope**. The speed at which you can move is affected by the slope of the ground or terrain features. This slope can be determined from the map by studying the contour lines—the closer the contour lines, the steeper the slope; the farther apart the contour lines, the gentler the slope. **Totally flat ground has no contour lines**.

- There are four (4) types of slope:
  1. Gentle
  2. Steep
  3. Concave
  4. Convex

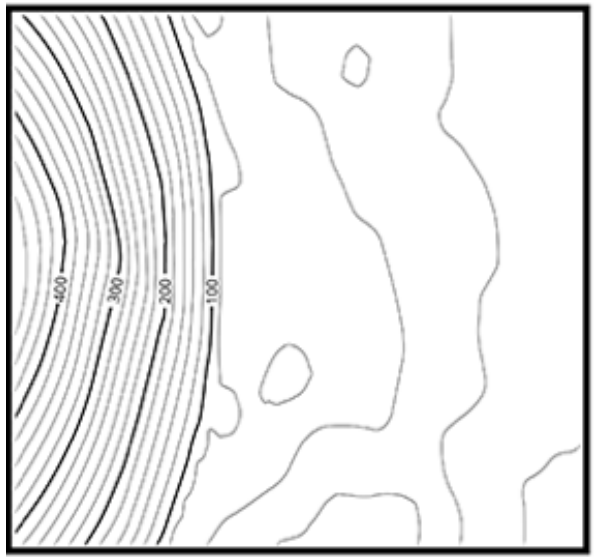
GENTLE SLOPE

Contour lines showing a uniform, gentle slope will be evenly spaced and wide apart. Easy walking.



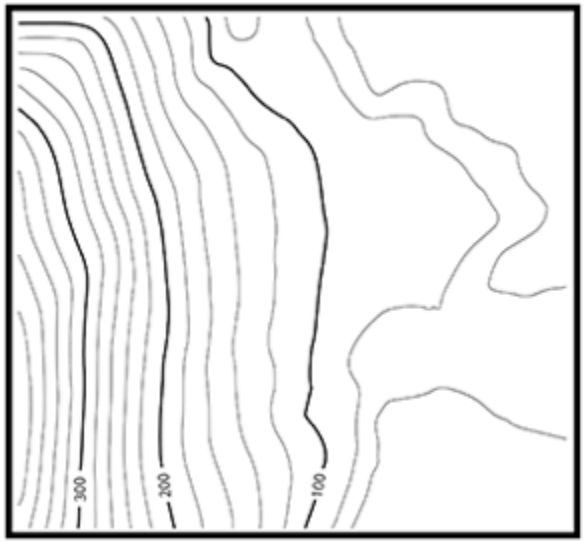
STEEP SLOPE

Contour lines showing a uniform, steep slope on a map will be evenly spaced, but close together. Very challenging, or impossible walking (contour lines may be so close that they create an impassable cliff line).



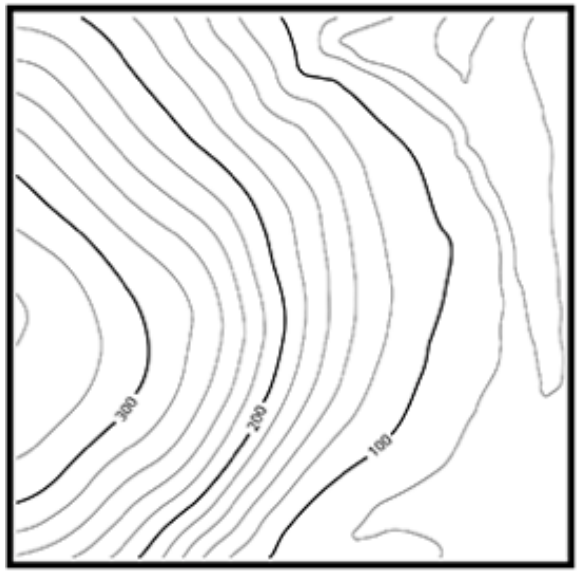
CONCAVE SLOPE

Contour lines showing a concave slope on a map will be closely spaced at the top of the terrain feature and widely spaced at the bottom. You may find the terrain increasingly steep and challenging.



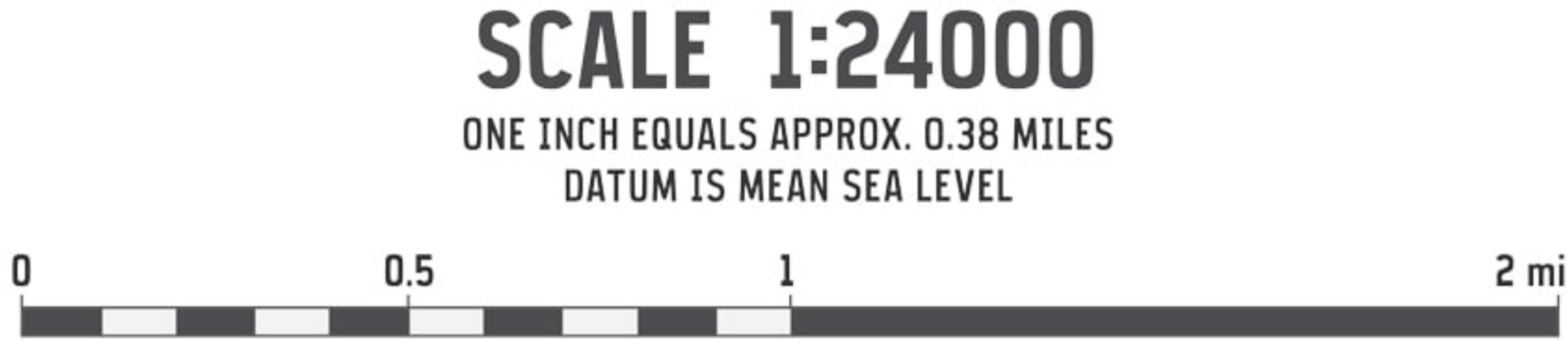
CONVEX SLOPE

Contour lines showing a convex slope on a map will be widely spaced at the top and closely spaced at the bottom. Going down the slope you may not see the slope or the terrain at the bottom, so extra care must be taken when descending.



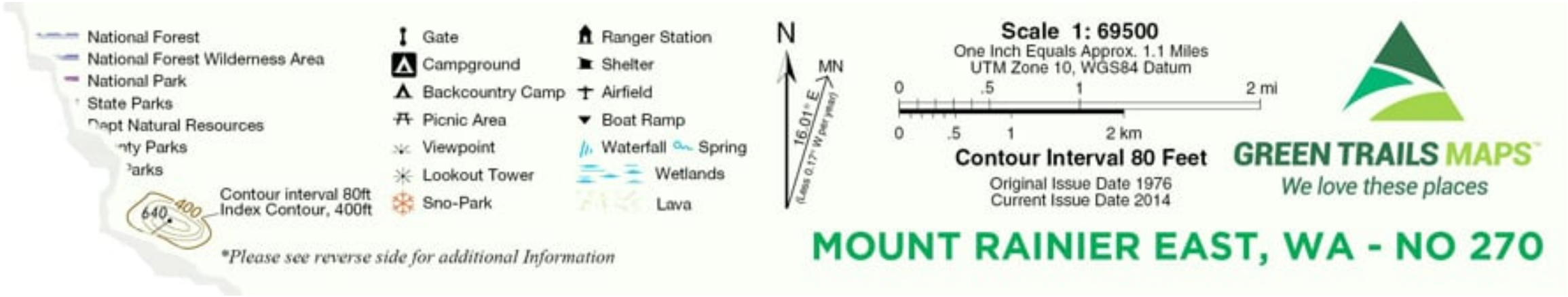
MAP SCALES

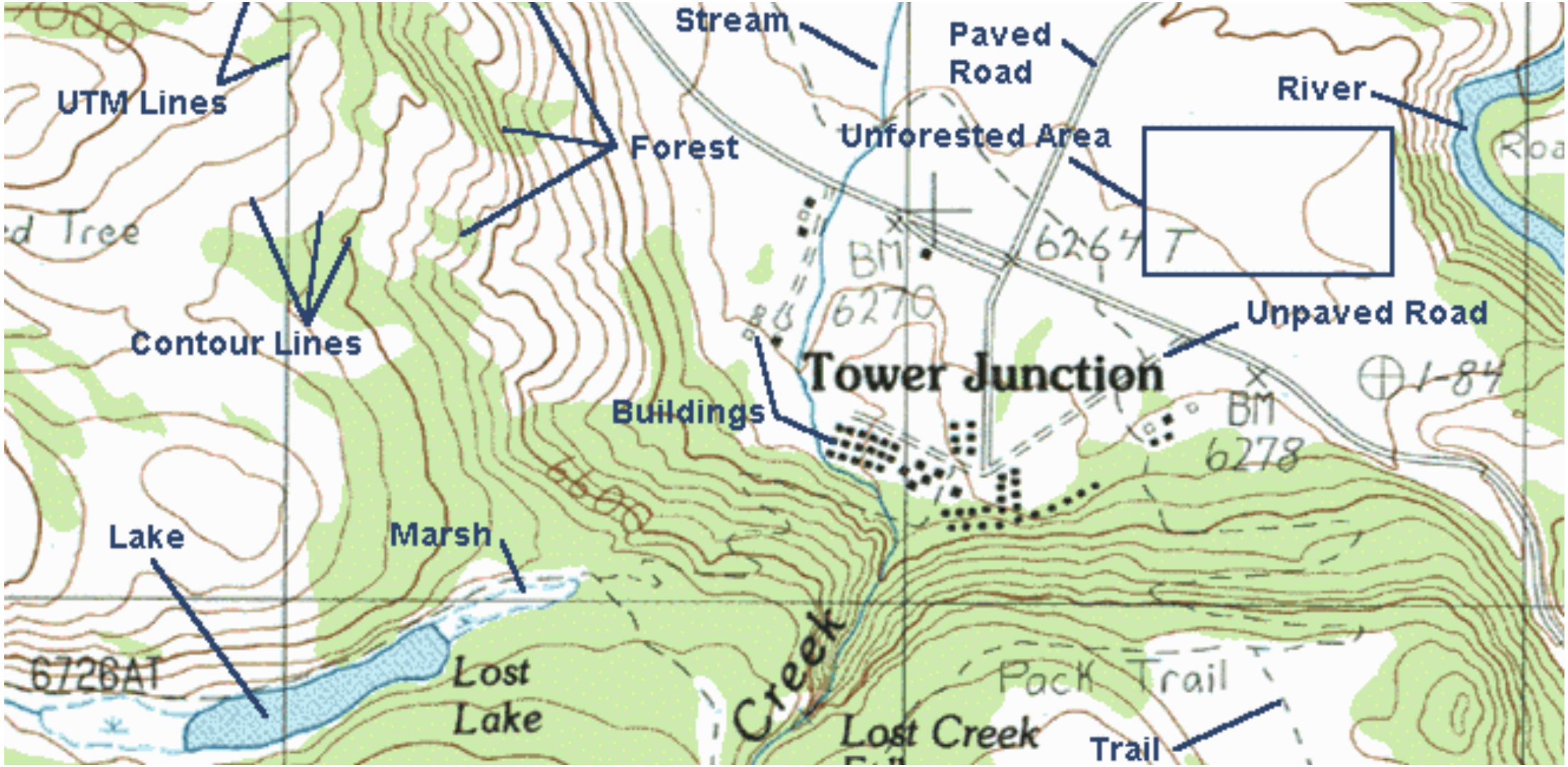
The map's scale tells you how detailed your map is. A 1:24000 scale, for example, means one inch on the map equals 24,000 inches of real-world terrain. If the scale ratio had a number like 1:65,000, though, that would mean that each inch on the map covered 65,000 inches of terrain. A map with that scale covers a larger area overall—but it has less detail within each square inch on the map.



MAP LEGEND

Look closely at the map legend. It's loaded with map-reading clues and navigational data. Start by studying what each line, symbol and color means. Generally, green indicates denser vegetation, while light or colorless areas suggest open terrain. And, as you'd expect, streams and lakes are shown in blue.




Stream
Paved Road
River
UTM Lines
Forest
Unforested Area
Contour Lines
Unpaved Road
Tower Junction
Buildings
Lake
Marsh
Lost Lake
Creek
Lost Creek
Trail
BM 6270
6267
BM 6278
I-84
Pack Trail

WHERE TO FIND TOPO MAPS

For day hikes and more precise navigation, you'll want a smaller scale map in your day pack. The level of detail is greater, with more individual features allowing for a greater degree of accuracy when you're finding your way from A to B. For hiking at nighttime, you will want a smaller scale map.

Use below link to find, download or order topographic maps:

Get Topo Map

Compass Navigation

COMPASS NAVIGATION

Orienteering – Is a sport that requires navigational skills using a map and compass to navigate from point to point in diverse and usually unfamiliar terrain whilst moving at speed

Participants are given a topographical map, which they use to find check points. Originally a training exercise in land navigation for military officers, orienteering has developed many variations. Among these, the oldest and the most popular is foot orienteering

TYPES OF COMPASS

There are two main types of compass

1. **Magnetic Compass**
   - Has a magnetic element (needle or a card) that aligns itself with magnetic lines of Earth's magnetic field to point to the magnetic poles of the Earth
2. **Gyro Compass**
   - Has a rapidly spinning wheel whose rotation interacts with the rotation of the earth until its axis of rotation is parallel with the Earth's and points to the Earth's rotational poles. This compass points to the true poles of the Earth. Primarily used in ships

TYPES OF COMPASS …

- **Marine Compass or Card Compass**
  - Has a needle that is fixed and a compass card that is mounted in fluid and rotates according to orientation. It is used on boats because the moving card absorbs much of the motion of a boat which makes it easier to read than a needle compass. Used in boats
- **Prismatic or Lensatic Compass**
  - Has a glass prism or a lens and a lid that has a hairline. These are used for lining up with an object whose bearing is sought. It also has compass card which rotates in the base. Used primarily by military
- **Baseplate Compass**
  - Has a magnetized needle or card immersed in fluid. This method lessens excessive swing and wobble and improves readability while reducing wear. It is placed on the rectangular base made of transparent plastic so a map can be read through it. Designed to be used with a map for all outdoor activities
- **Solid State Compass**
  - Are found in electric devices. It often has two or three magnetic field sensors from which microprocessor reads data about the orientation of the device. Used in most electronic gadgets

TYPES OF COMPASS …

- **Qibla Compass**
  - Is used by Muslims to show the direction to Mecca so they would know where to turn while praying
- **GPS Compass**
  - Uses satellites in a geo synchronous orbit over the Earth to show exact location and direction of movement of bearer
- **Astrocompass**
  - Uses positions of various astronomical bodies to find true north. It is used in polar regions where magnetic compasses and gyrocompasses are unreliable. It uses current time and geographical position in the form of latitude and longitude

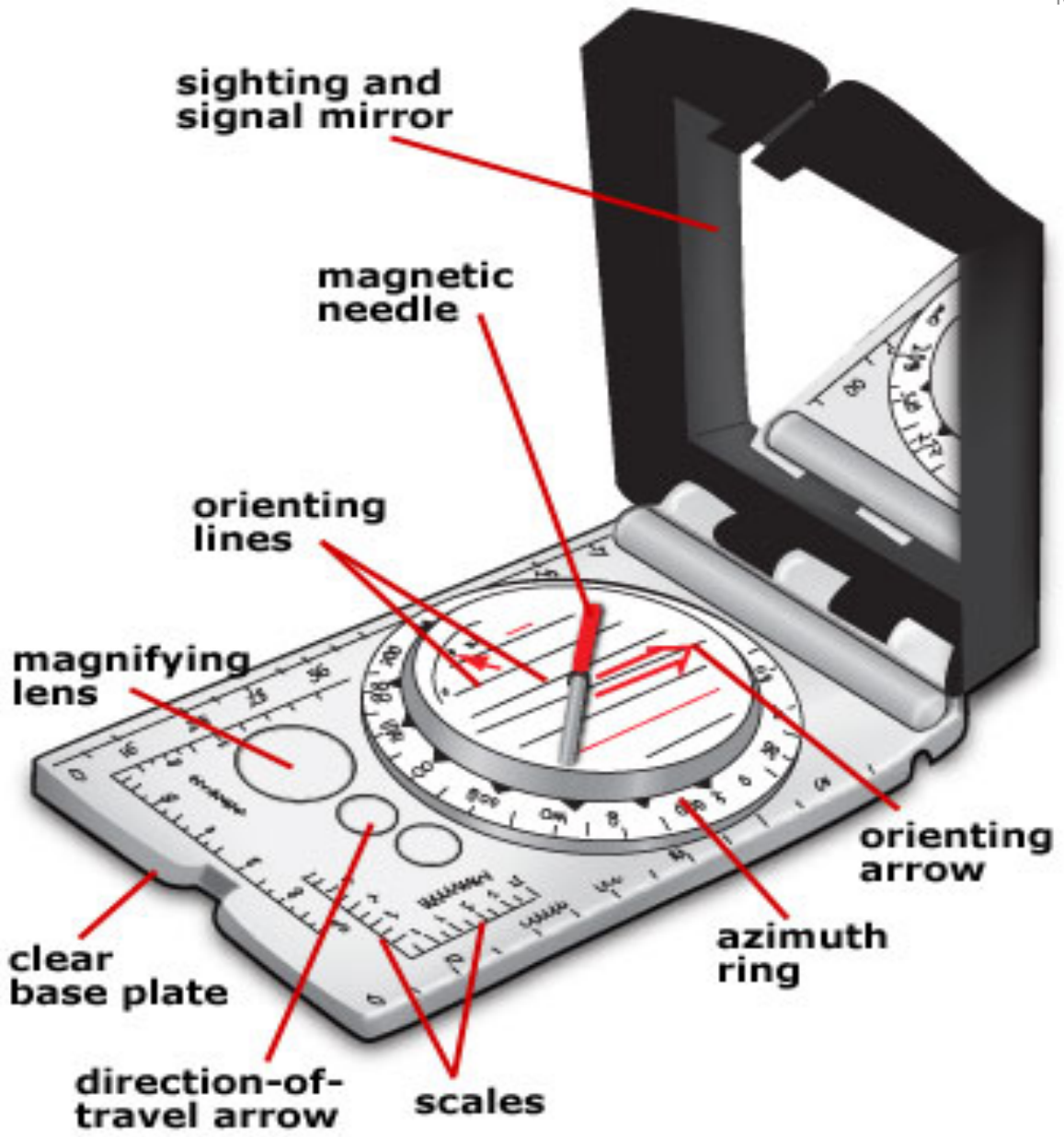
WHAT TO GET?

Within magnetic compass arena, there are several types of compass. We will review only the most practical and used compass for hiking and all outdoor activities in the market and will skip specialized compasses:

1) Baseplate Compass
2) **Mirrored Baseplate Compass**
3) Lensatic Compass. Primarily used by military and is not in scope for this presentation

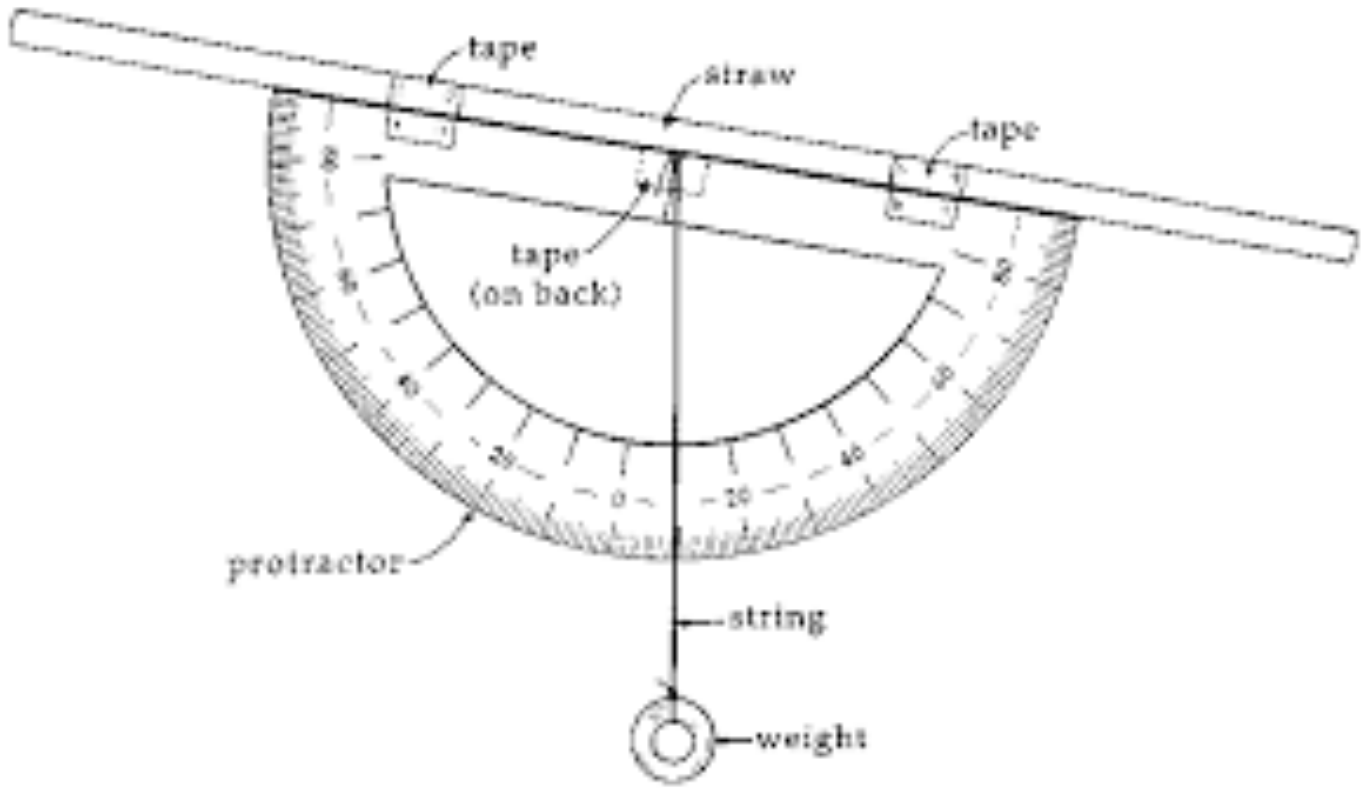
FEATURES TO LOOK FOR:

- Orienting Lines / Meridian Lines
- Orienting Arrow
- Rotating Housing with Degrees /Azimuth Ring
- **Adjustable Declination**
- Magnetic Needle that quickly points to North
- See-through baseplate with straight edge
- **Sighting / Signaling Mirror**
- Direction of Travel Arrow
- Index Pointer, Index Line
- Magnifier
- Scales / Ruler
- **Clinometer**



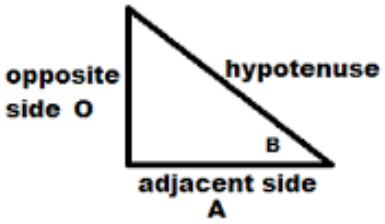
WHAT IS CLINOMETER

- A **clinometer** is a simple instrument which is used to measure the angle of a slope
- **Using principles of trigonometry**, the height of tall objects (for example a tree) can be calculated from the angles measured (see next slide)
- **Suunto MC-2** compass is equipped with a clinometer dial



CALCULATE HEIGHT OF A TREE

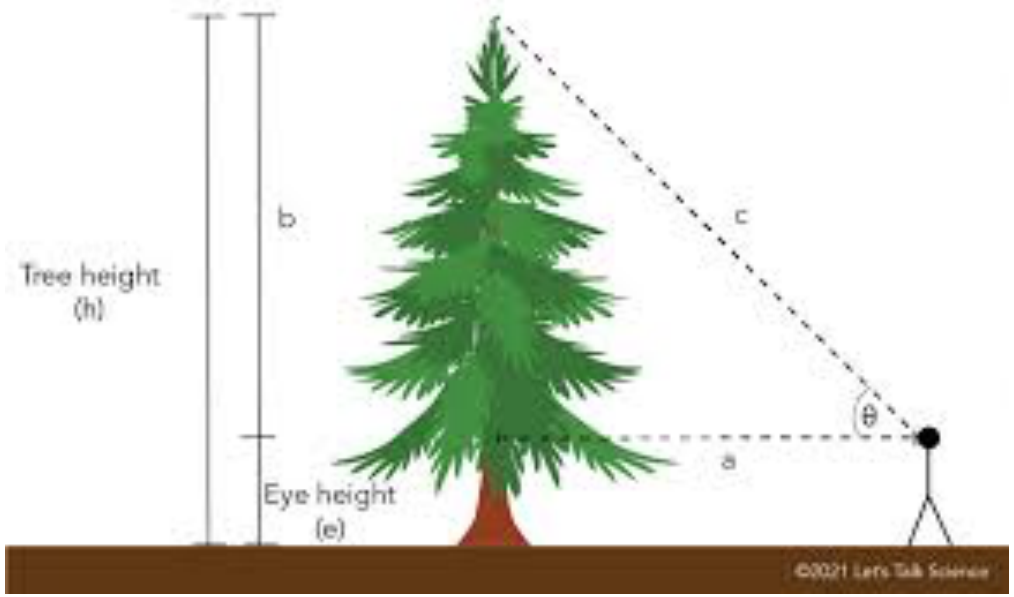
- The height of the tree is calculated by measuring the distance from the tree and the angle of elevation of the top of the tree (measured by MC-2 Clinometer).
- The tangent of the angle is the tree height divided by the distance from the object.



$$\tan B = \frac{\text{opposite}}{\text{adjacent}} = \frac{O}{A}$$

$$\tan(64°) = \frac{h}{(48\ ft)}$$

$$h = (48\ ft) \times \tan(64°) = 98\ ft$$



You need to add height of the person to the result to get tree height

HOW TO MEASURE ANGLES & HEIGHTS
6 MINUTES

THINGS TO WATCH OUT!

The type of compass used in most outdoor activities is known as "**magnetic compass**". This means the compass needle is affected by the magnetic fields around you. So, avoid the following mistakes while using a compass by keeping the it away from:

- Your body
- From metal objects (on your clothing: pens, cell phone, etc.)
- Power lines
- Bridges or underground pipes

Distance yourself from possible disruptions to get a good reading

A SIMPLE EXERCISE

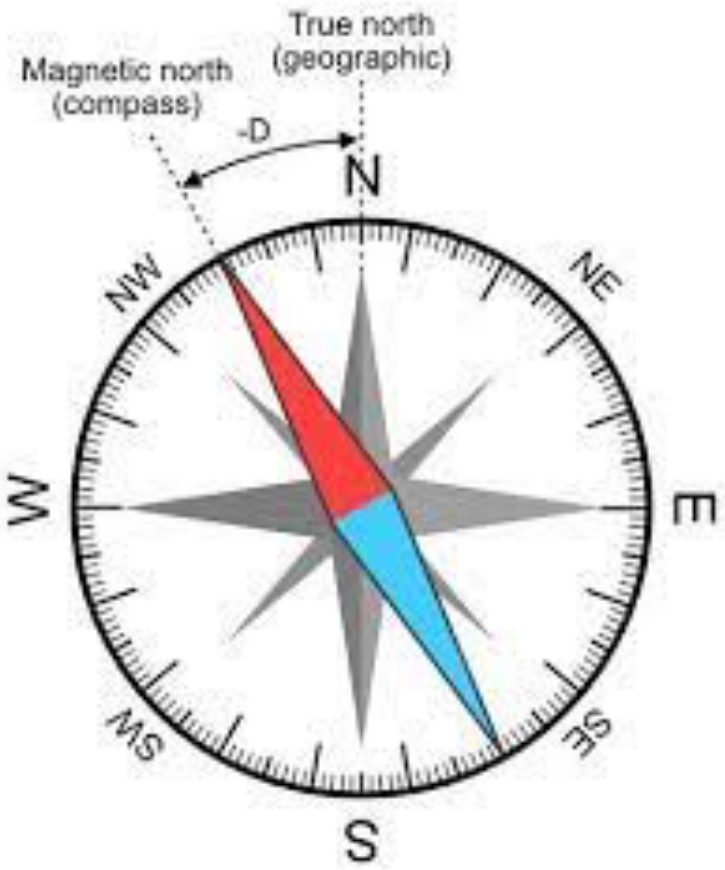
- Decide which direction you want to travel (let's say East)
- Rotate the compass dial so that EAST marker on the rotating bezel lines up with index line
- Hold compass, chest high, level, away from your body, then turn your entire body (including feet) until magnetic needle is inside the shed (the red housing)
- Look at the **direction of travel** and read the number at the index line
- That is the direction you want to travel (EAST)
- Easy?

PREPARE YOUR COMPASS AND MAP

Before using a compass and a map for navigation, the following steps must be taken:

1. Adjust for Declination
2. Orient the map

ADJUST FOR DECLINATION

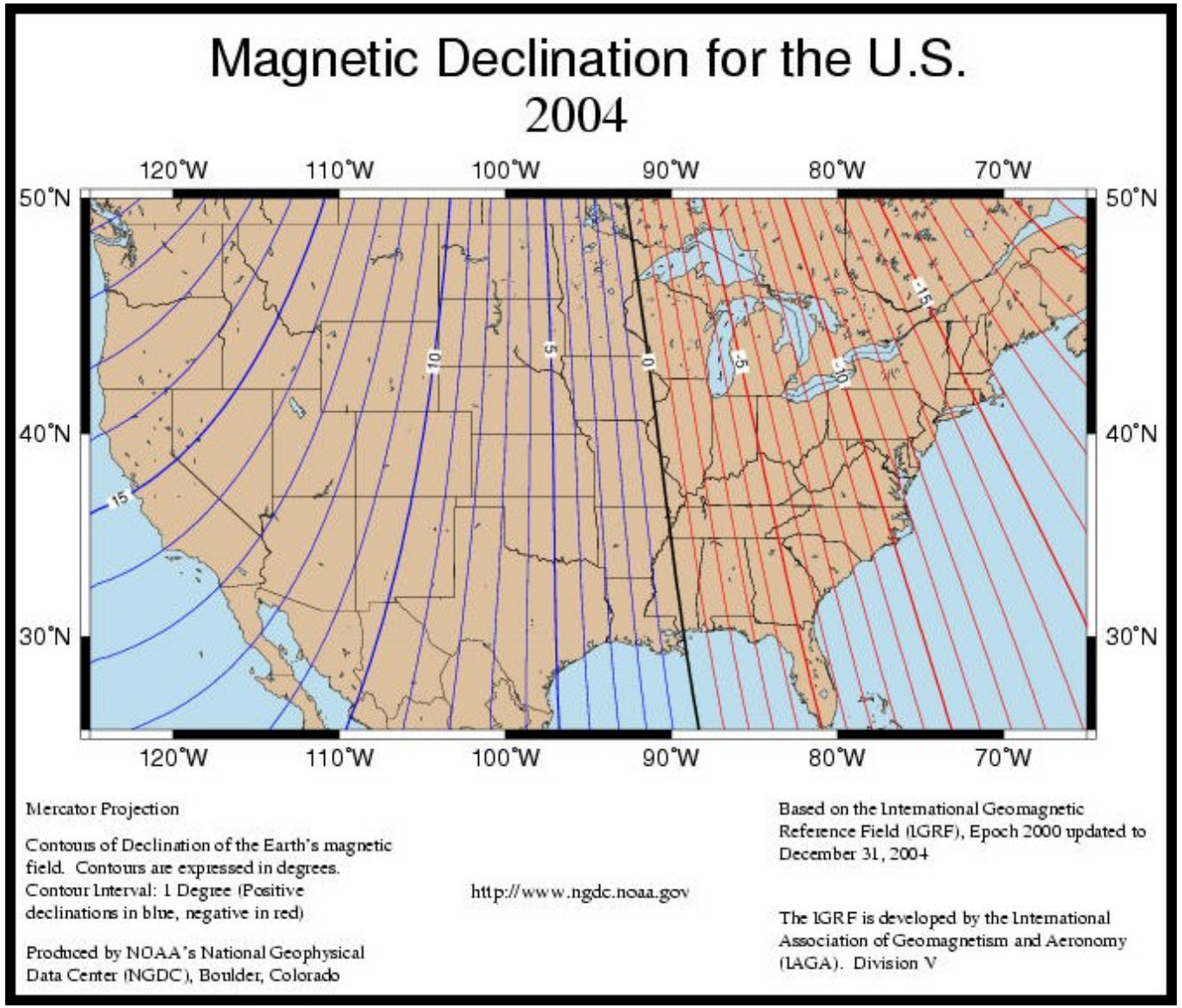


Please note: It is critical to adjust your compass for declination.

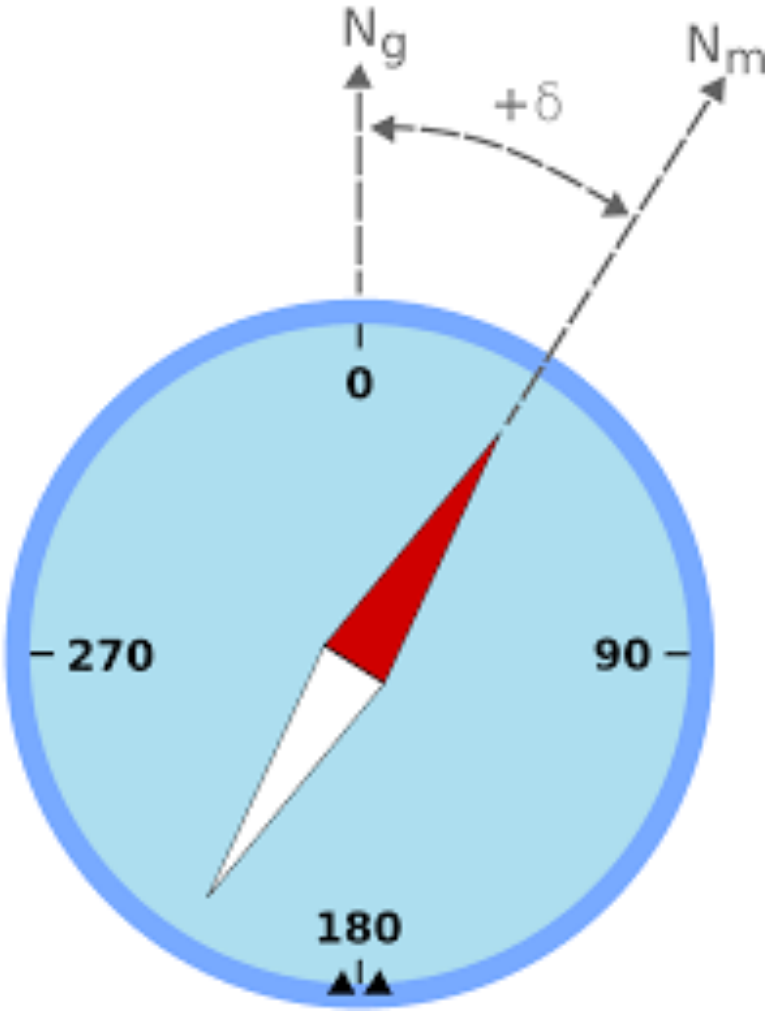
- In the continental U.S., **declination** can vary from nearly 20 degrees east in places on the West Coast to nearly 20 degrees west in places on the East Coast. When you're navigating in the wilds, degrees matter. A 15-degree error, for example, on a mile-long hike puts you a quarter-mile away from your destination
- Before you can adjust for declination, you must find its value in your trip area. Topo maps list it, but the value varies over time. So, check the map's revision date or, better yet, consult the **National Oceanic and Atmospheric Administration** (NOAA) https://www.noaa.gov/ or use NOAA Calculator

ISOGONIC CHART

Isogonic chart shows lines on the Earth's surface of the earth along which the declination has the same constant value, and the line with the declination of zero is called **Agonic** line



DECLINATION ADJUSTMENT

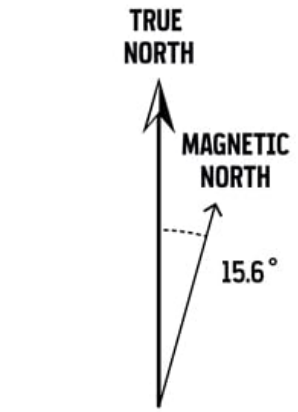


There are two (2) ways to adjust for declination:

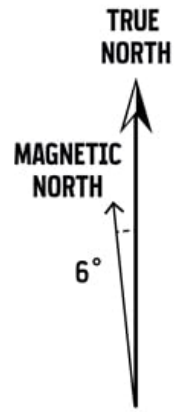
1) Adjust your compass
   I. Compass has adjustment screw
   II. Compass has no adjustment screw
2) Adjust your map

Declination Correction: Adjustable Compass

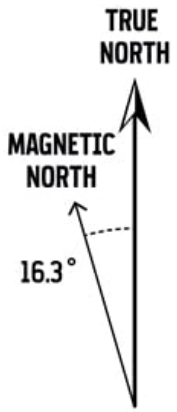
- It varies with different compass brands. Here is how you adjust a **Suunto MC-2** compass for declination:
- Turn the compass over
- Insert the metal key (provided with your compass) into the adjustment screw
- Turn the key until the declination indicator is the correct number of degrees east or west of 0° (15.6 degrees East in this example)



Mount Rainier NP
15.6° East



Central Great Smoky Mountains NP
6° West



Acadia NP
16.3° West

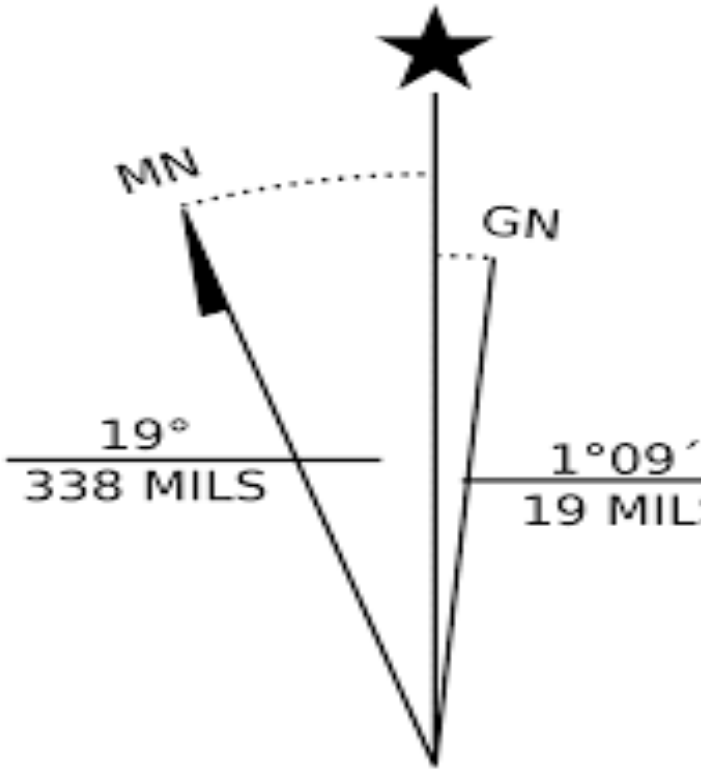
NOTE: ADJUSTABLE COMPASS

Once you adjust for declination, you won't have to worry about it again **until** you move to a new location where magnetic declination might be different

Declination Adjustment: Fixed Compass

- When using a compass **without** adjustable declination, make sure the direction of travel of arrow is pointing directly away from you
- Now rotate the compass dial until the red magnetic needle overlays the orienting arrow (red in the shed)
- Observe the reading at the index line.
- If local magnetic declination is **positive**, (magnetic north needle is on the east side of True North) then **add the** declination amount (or, turn the dial to the left).
- If the local declination is **negative**, (magnetic north needle is on the west side on True North), then **subtract** the declination amount (turn the dial to the right)
- The number at the index line after adding or subtracting is the corrected direction of travel

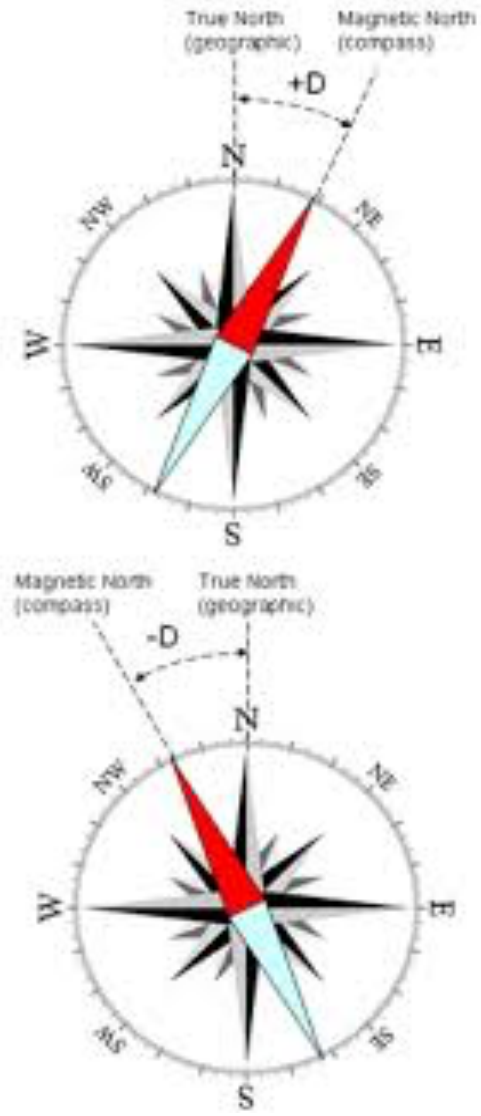
GN = Grid North. No compensation is required



NOTE: FIXED COMPASS

Declination adjustment must be repeated every time a bearing is taken, and compass is read.

DECLINATION ADJUSTMENT
ADJUST YOUR MAP



This is a techniques used by some to simplify navigation using a compass

It involves drawing parallel lines on the map to align with degree of declination and use those lines instead of the Meridian lines (already printed on the map) when taking a bearing. This eliminates the need to adjust your compass for declination

HOW TO ADJUST FOR MAGNETIC DECLINATION

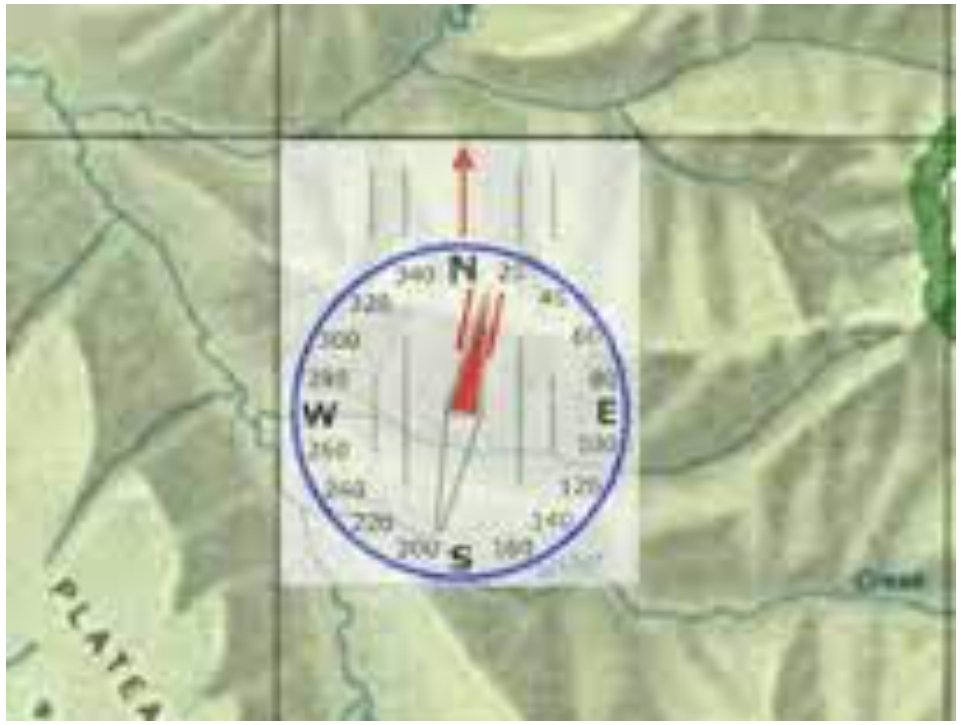
4:22 MINUTES

ORIENT YOUR MAP

A **map** represents the real world.

By **orienting** a **map**, you are positioning it, so its North is pointing to **True North**. A map so lined up is easier to interpret and follow than a map spread out haphazardly. Once you know where north is, you can then read your map and your surroundings with more accuracy.

ORIENT YOUR MAP CONTINUES..



1. Make sure your compass is adjusted for magnetic declination
2. North is always at the top of any map. Double-check by making sure the map title or legend text is the correct way up or find the maps north arrow
3. Place your compass base plate on your map so the edge of the compass is aligned with the north-south meridian lines. You should notice that the direction of travel arrow should be pointing at the top of the map
4. Rotate the map and compass baseplate **together** until the compass needle is “boxed” in the red orienting arrow. This is commonly known as putting **“the red in the shed”**
5. Your map is now oriented!

ORIENT YOUR MAP NOTES…

Note 1:

If your compass doesn’t have a declination adjustment key, simply make the adjustment on the spot by rotating the map required number of degrees east or west

Note 2:

Do a quick check by looking around you to see that all features represented on your map are where they should be in the terrain

COMPASS NAVIGATION

Why do you need a compass?

A compass helps you orient the map, identify land features and locate your position. You may hike for days on a trail and never even use the compass. Take a wrong turn and then a compass suddenly becomes one of the most important tools in your pack.

It's a must for every outdoor enthusiast, with or without a map. It puts the "**invisible power of direction**", Earth's magnetism at your fingertips.

1. Find the direction you wish to travel (also called **finding your bearing)**
2. Find your exact location on the map (known as **triangulation**)

SKILLS TO MASTER ☺

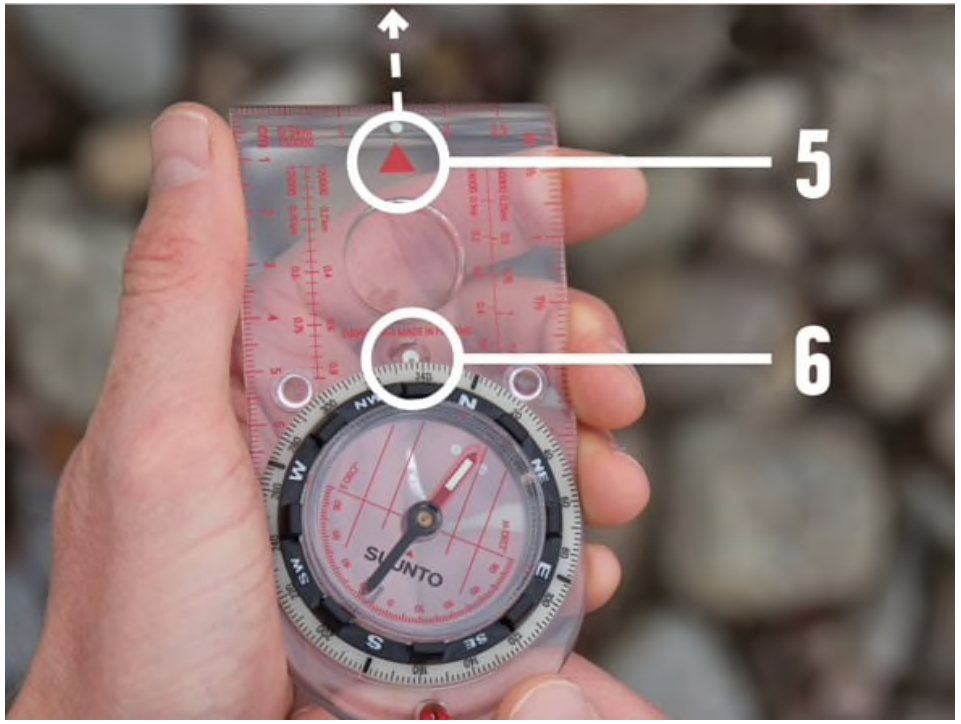
1) Find your bearing on a map
2) Apply bearing obtained on the map to field
3) Back Bearing – Trace back to where you came from
4) Find your bearing in the field
5) You now where you are, and you want to identify one or more distant landmarks
6) Find you location on a trail. You don't know where you are (exactly), but you can identify one distant landmark (see Triangulation)
7) Find your location anywhere. You have no idea where you are but can identify two or more distant landmarks (see Triangulation)

FIND YOUR BEARING ON A MAP

1) Identify a landmark (hill, lake, structure, etc.) and find it on your map
2) Set your compass on the map so that the straight side of the baseplate lines up between your current position (1a) and the landmark (the campsite 1b in this example)
3) Make sure the direction of travel arrow is pointing in the general direction of the landmark (campsite)
4) Now rotate the bezel until the orienting lines on the compass are aligned with the north-south grid lines of your map. (***The north marker on the bezel must be pointing north on the map***)
5) Look at the index line to **read the bearing** you've just captured

APPLY BEARING OBTAINED ON THE MAP TO FIELD

5. Hold the compass with the direction of travel arrow pointing away from you
6. **Rotate your body** until the magnetized needle is inside the orienting arrow (remember **"the red in the shed").** The direction of travel arrow (#5 on picture) is now facing the bearing you captured, and you can follow it to your destination



BACK BEARING

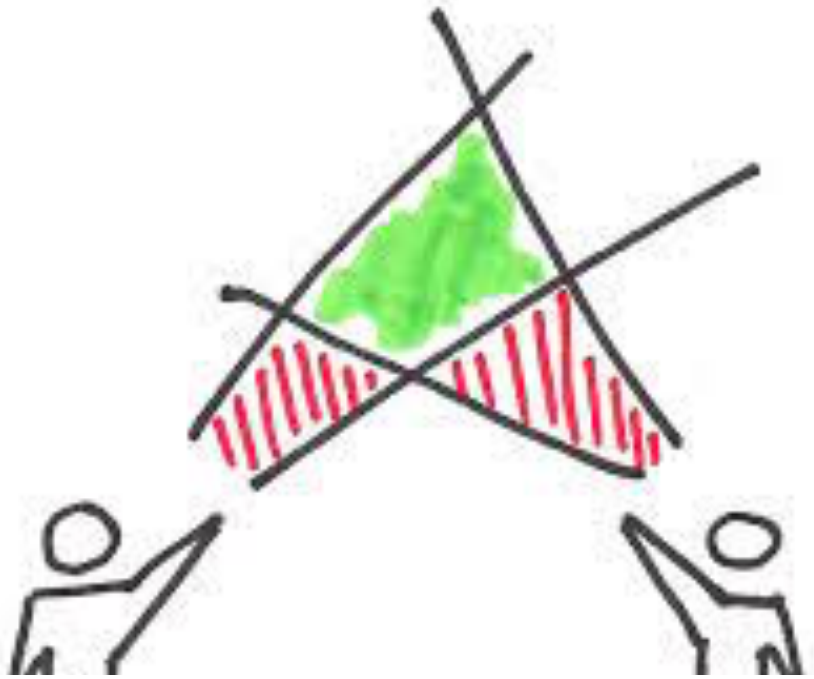
When in the wilderness you may find it necessary to retrace your steps. Just turning around and retracing what you think was your path leaves too much room for error and can potentially get you lost.

In order to retrace your steps accurately, you'll need to calculate what's known as a **'back bearing**' or 'back azimuth. Here is how:

- If your initial bearing is **180 degrees or less**, just add another 180 degrees to determine your back bearing. Conversely, if the bearing you were traveling is **greater than 180** degrees, subtract 180 degrees from it to determine your back bearing

TRIANGULATION

PROCESS OF PINPOINTING YOUR LOCATION BY TAKING BEARINGS TO THREE REMOTE POINTS



1. Adjust for magnetic declination
2. Orient your map
3. Identify two (preferably three) landmarks
4. Take field bearings to each landmark
5. Apply bearings to the map
6. Draw bearing lines on the map
7. Intersection of the lines identify your location

FIND YOUR BEARING IN THE FIELD

1) Find a landmark that you can also identify on your map
2) Hold your compass flat with the direction of travel arrow pointing away from you and directly at the landmark
3) Now rotate the bezel until the magnetized needle is inside the orienting arrow (red in the shed)
4) Look at the index line to **read the bearing you've just captured**

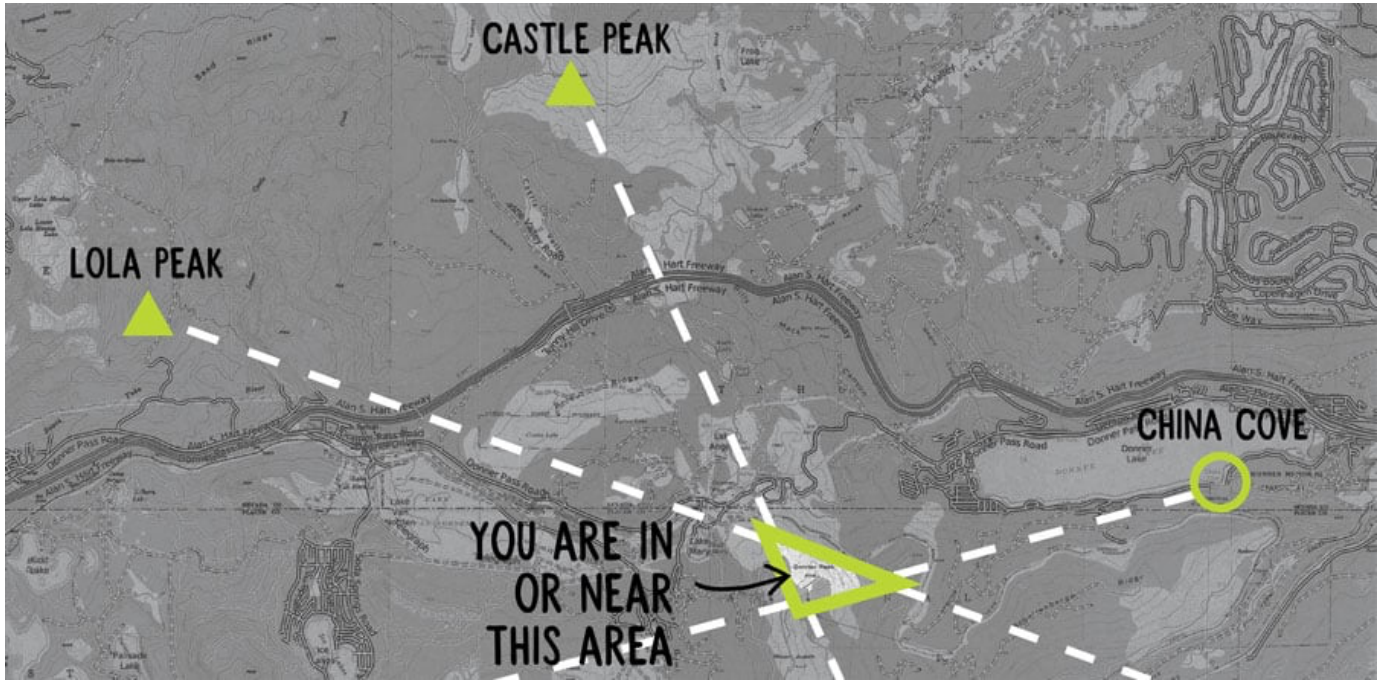
TAKE A FIELD BEARING AND APPLY IT TO THE MAP

5) Lay your compass on the map and align one corner of the straight edge with the landmark (you took bearing for)
6) Making sure that the direction of travel arrow remains pointed in the general direction of the landmark (6a)
7) Rotate the entire baseplate until the orienting lines are running north/south (6b) and the north marker on the bezel is pointing to north on the map (6c)
8) Now you can draw a line on the map along the straight edge of your compass (7a)

COMPLETE TRIANGULATION

9) Repeat steps 5,6,7 and 8 for two (2) remaining landmarks

10) If the lines you draw meet at a single point, **that's your location.** Most of the time, though, the three lines will form a small triangle. Your location will be somewhere in or near that small area



⚠ **If the lines form a very large triangle, recheck your work because you have at least one significant error**

CONGRATULATIONS!

- What you heard today will make sense and become more useful only if you use it, practice it, and make it a habit of constantly testing your skills when outdoors or even when going for a walk in your neighborhood
- Carry and use your compass on every outdoor event. Test your skills by taking bearings and finding your position on the map
- Download topo map of the area you are planning to be the following week. Remember, It takes few days for the map to arrive (from USGS)
- Compass is one of the oldest navigational tools that is still used by military, transportation and countless other applications. Remember, GPS and electronic gadgets are great until they stop working. **Compass never fails!**

NAVIGATION COURSES

Map and Compass Navigation Courses

- Such courses are offered by REI (Recreation Equipment Incorporated)
- NOLS (National Outdoor Leadership School)
- WMI (Wilderness Medicine Institute)
- SOLO (Stonehearth Outdoor Learning Opportunities)
- Orienteering clubs, wilderness conservation groups, local college outdoor education classes, wilderness skills and survival classes
- If you don't find anything locally, check with the offices of the nearest **National Forest**, **National Park Service**, **Bureau of Land Management**, **state park**, **state Department of Natural Resources**, or local **Boy Scout** troops

REFERENCES

The contents of this presentation was derived from dozens of articles, blogs, posts, and websites, and from various sources including the following entities:

1. National Parks Association
2. REI
3. Sierra Club
4. USGS Website
5. National Oceanic and Atmospheric Administration
6. Adventure.com
7. Backpacker.com
8. Thecompassstore.com

TANGENT TABLE

Angle	Tangent	Angle	Tangent	Angle	Tangent
0°	0	31°	0.6009	61°	1.8040
1°	0.0175	32°	0.6249	62°	1.8807
2°	0.0349	33°	0.6494	63°	1.9626
3°	0.0524	34°	0.6754	64°	2.0503
4°	0.0699	35°	0.7002	65°	2.1445
5°	0.0875	36°	0.7265	66°	2.2460
6°	0.1051	37°	0.7536	67°	2.3559
7°	0.1228	38°	0.7813	68°	2.4751
8°	0.1405	39°	0.8098	69°	2.6051
9°	0.1584	40°	0.8391	70°	2.7475
10°	0.1763	41°	0.8693	71°	2.9042
11°	0.1944	42°	0.9004	72°	3.0777
12°	0.2126	43°	0.9325	73°	3.2709
13°	0.2309	44°	0.9657	74°	3.4874
14°	0.2493	45°	1.0000	75°	3.7321
15°	0.2679	46°	1.0355	76°	4.0108
16°	0.2867	47°	1.0724	77°	4.3315
17°	0.3057	48°	1.1106	78°	4.7046
18°	0.3249	49°	1.1504	79°	5.1446
19°	0.3443	50°	1.1918	80°	5.6713
20°	0.3640	51°	1.2349	81°	6.3138
21°	0.3839	52°	1.2799	82°	7.1154
22°	0.4040	53°	1.3270	83°	8.1443
23°	0.4245	54°	1.3764	84°	9.5144
24°	0.4452	55°	1.4281	85°	11.4301
25°	0.4663	56°	1.4826	86°	14.3007
26°	0.4877	57°	1.5399	87°	19.0811
27°	0.5095	58°	1.6003	88°	28.6363
28°	0.5317	59°	1.6643	89°	57.2900
29°	0.5543	60°	1.7321	90°	No solution
30°	0.5774				

THANK YOU!

QUESTIONS, SUGGESTIONS, COMMENTS