PCTA Trail Skills College Curriculum

Instructor Planning Guide

Course 300. Rock Retaining Walls

Learn fundamentals of rock construction including an emphasis on effective and safe use of rock bars, the critical tool for all rock work. We'll tackle basic rock placement techniques for rock walls to last the ages. Recommended after taking Course 203, which covers rock check steps and waterbars.

STUDENT SKILL OUTCOMES:

- Understanding of ideal rock size & shapes for rock structures.
- Safe quarrying and transport of rock, especially safe use of rock bars.
- Construction of effective rock walls from one to three tiers.
- If time allows, side projects include installing guide rocks, rip rap, and other minor trail armoring.

KEY TERMS:

rock shopping, rowing rocks, mechanical advantage, batter, rock crush, guide rocks, riprap, foundation rock, cap rock, rock armoring, mineral soil

TRAIL MAXIMS:

"If you can pick it up alone, it's too small." "Better to slide it than roll it; better to roll it than carry it; and don't carry it alone." "Give me a lever long enough, and I can move the world" (Archimedes). "Less talk, more rock."

TOOLS NEEDED PER 8 STUDENTS:

2 fire shovels, 1 McLeod, 1 adze hoe, 2 Pulaskis, 4 pick mattock, 2-4 small chisel-tipped rock bars, 4 large rock bar, 1 tamping bar, 4 five-gallon buckets or canvas dirt bags, 2 heavy sledge hammers, 2 single jacks (a.k.a. mash hammer, mason hammer), rock stretcher/sling, 1 - 2" cold (rock) chisel (if available), a wheel barrow or hand truck if outside Wilderness, 20 pin flags, 6' malleable wire. Extra eye protection.

WORK SITE REQUIREMENTS:

Trail on moderate to steep sideslope needing guide rocks, edge reinforcement and 1-2 short rock walls to build or rebuild, could be inside the corner of a switchback. Ideally such a trail is near a trailhead, with nearby suitable rock. If possible, the trail should allow horses, to emphasize the importance of using large well placed rocks.

KEY CONCEPTS:

1) Safety Documents and Concerns: Personal Protective Equipment (PPE), Job Hazard Analysis (JHA), Tailgate Safety Session (TSS), Emergency Action Plan (EAP)
2) Trail Crew Leave No Trace: Have a positive impact on the land through trail work and be sensitive to off trail and camping impacts.
3) Where retaining walls are appropriate
4) Shape and size of ideal wall rocks
   - Roughly rectangular
   - If you can lift it, it's too small
5) Steps in building a rock retaining wall
   - Excavate a solid, insloped foundation
   - Anchor the first rock, or use a large first rock
   - Set one tier at a time, keeping level, tops insloped
   - Maximize contact and eliminate wobble
     - Simple rock shaping
     - Shims: only from inside, never from outside face
   - In-leaning batter
   - Fill with crush; pack tight
   - Tie stones for taller walls
   - Cap stones should be very large
6) Other uses of rock (sample only if time allows)
   - Rock Checks
   - Guide Rocks
   - Riprap
   - Rock Armoring
   - Drain Crossings
7) Where to look for rocks: uphil and not from sensitive streambeds
8) Using fulcrums to pry rocks loose
9) Safe rock transport with rock bars, picks, and slings or stretchers
   - Rowing or skidding is better than rolling
   - Rolling is better than lifting
   - Lifting should be done with multiple persons, using slings or stretchers

BACKGROUND

For a special breed, building with rock can be one of the most gratifying forms of trail work. When done skillfully, with patience, care, and hard work, it is possible to build rock structures such as walls, steps, and tread armoring that will last for generations. I have seen a Roman arch trail bridge still standing after nearly 2000 years!

Safety Awareness: Working with rock is potentially among the most dangerous tasks in trail work. Careless workers regularly crush fingers, hands and toes. Strained or severely injured knees and backs are much too common. This is usually because some people work too fast, carelessly and take on too much weight by themselves or, they miscommunicate when moving a rock cooperatively.

Contrary to expectation, many of the best rock workers are women and men of average or even modest size and strength. To move big rocks they must collaborate, work methodically and use their brains rather than brawn.

Do not tolerate careless or macho rock work. Insist on full PPE at all times. Never work directly below other rock workers without a clear escape route. Close the trail when appropriate. Trail workers have been killed by runaway rocks.

Establish the protocol of immediately shouting “ROCK! ROCK!” if another volunteer, hiker, or equestrian ever gets away down a hill. Even if you think it will stop before going far, shout out without hesitating.

Trail Eyes: Seeing where a rock placement or wall is needed is an acquired and essential art. The last thing you want is to spend several hours or days of hard labor finding, transporting and placing the perfect rocks, only to realize they were unnecessary or in the wrong location.

Tool Care: Take extra care that any equipment you use for moving large rocks is in good shape to ensure that it does not fail.

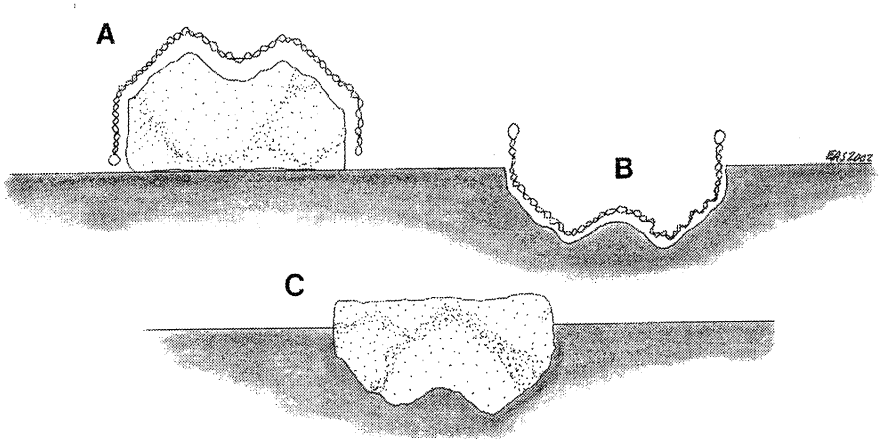
Quality Work: We use rock because it can last “forever”, but ONLY IF we build it right. Poor quality rock work will fail faster than wood rots, especially with horses on the PCT. “If you’re gonna do it, do it right.”

Rock Retaining Walls

Before you start, make sure to explain to students why a retaining wall is needed at this site, and give other examples of situations where retaining walls may be appropriate.

Ideal rock... and real rock. The ideal rock is roughly rectangular with at least a flattish top and bottom. It should be big enough that it takes two or more people to carry it, though it’s safer to skid or roll large rocks (see maxims above). Identify your largest and best shaped

Figure 1. Using a length of malleable wire molded over a rock (a), will allow you to dig the foundation hole (b) to match the irregular bottom of the rock. This results is a well-seated and stable foundation rock (c). (IMAGE COURTESY OF VOC)



rock for the ***foundation rock***, though it can have an irregular under side if setting it in soil (rather than on rock).

In many locations ideal rocks are hard to come by, though you should always be willing to scour the landscape to find the best available (an endeavor known to some as ***rock shopping,*** see additional information below). Getting new folks to look far and thoroughly enough is a challenge, but must be stressed.

Ultimately, use the best rock you can find, which usually means some irregularities in shape and size. However, don't try to build a large durable structure from small odd-sized rocks. It ain't gonna work and isn't worth the effort. Wood is likely a better choice in such situations.

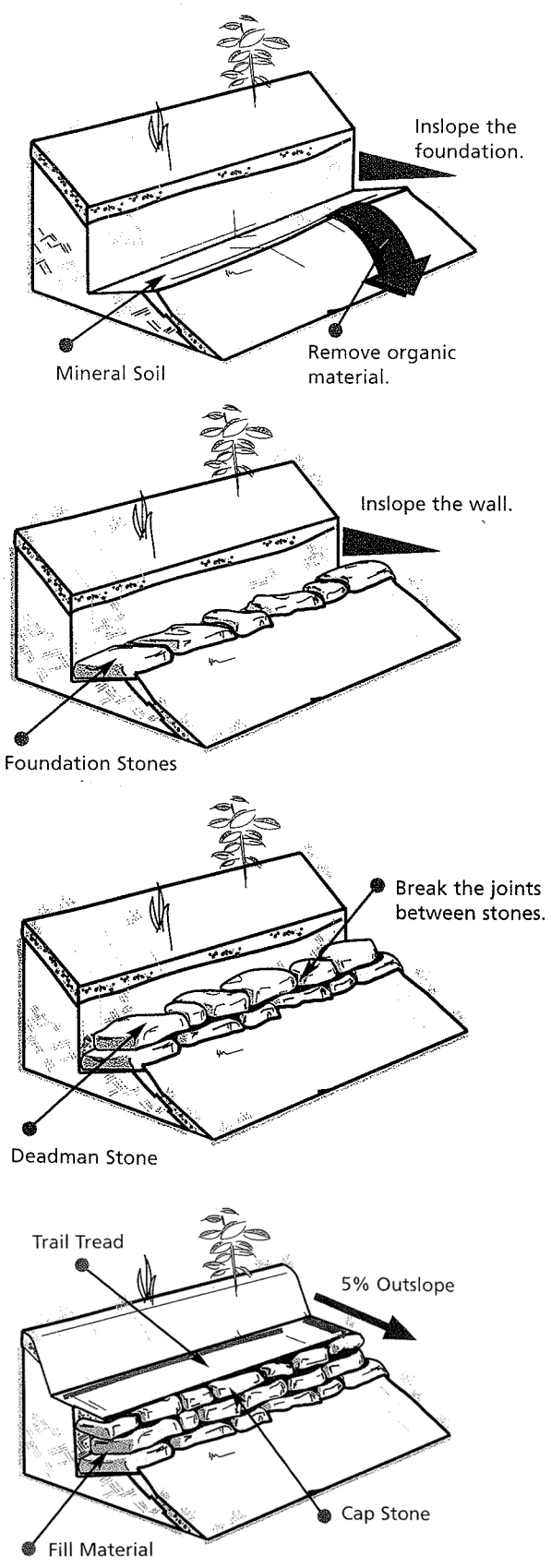
Any ***mineral soil*** excavated during the project should be stockpiled, not just scattered about. If there is excess dirt after the project is complete, look for cupped tread or holes from mined rock to fill – never let good dirt go to waste.

When building a rock wall, begin by excavating a solid, insloped foundation. As an anchor for the wall, butt the first and lowest foundation rock against a boulder or bedrock, or simply use a very large first rock. One method is to set the center stone first, so that two sets of workers can then be engaged in fitting rocks in opposite directions. However, students should only be allowed to set one course (tier) at a time, and try to keep each course level across the top.

Each rock should be set in a way that maximizes contact and eliminates wobble. If you have a chisel and mason's hammer, show students how to chip off bits in order to make rocks fit better. (However, more sophisticated techniques for shaping rocks should be reserved for more advanced classes or projects). If necessary to stabilize the next course, wedge (shim) rocks may be used, but only on the inside of the wall. Small rocks should never be wedged into the outside face, because they will eventually fall out.

It is crucial that the top surface of each set rock is insloped, so that the next rock on top of it won't slide out. Overlap rock joints with each successive tier. Make sure the outside face of the wall has an in-leaning ***batter*** of 1 to 3 inches per foot of wall height. As each course is set, fill large crevices from behind with fitted small angular rocks. Then, fill behind the whole tier with gravel or ***rock crush***. Do not use round rocks for fill; they act as ball bearings and do not adequately stabilize the larger rocks. Ensure the fill is packed so it has no room to shift or wash out. By the time each wall

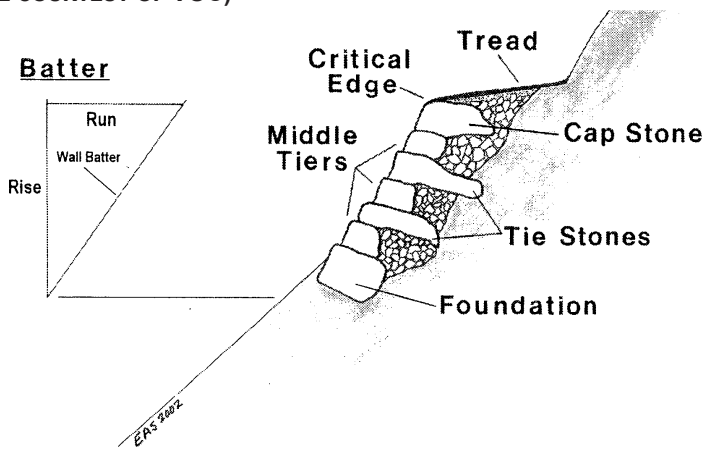
Figure 2. Step to constructing a rock retaining wall. (IMAGE COURTESY OF IMBA)



rock is set, and packed tight, it SHOULD NOT MOVE, even when you dance a jig on it.

For taller walls, by the time your wall is half its planned height, you should start incorporating what are known as ***tie stones*** (aka headers). These are long stones laid perpendicularly to the wall, rather than parallel to the other stones. The idea is to tie the structure into the slope behind it.

Figure 3. Side view of a wall illustrating the different elements of the structure. This wall and the hillslope have been drawn at an exaggerated angle to help illustrate the concept of batter (run over rise). The batter here is almost 1:1 but it would actually be about 1:4 for most walls. (IMAGE COURTESY OF VOC)



Top tier ***cap stones*** must be very large and stable to prevent horses from dislocating them. The cap surface of some rocks can be high and irregular to encourage traffic to stay away from the trail edge. Such cap stones thus double as guide rocks. Compacted mineral soil can be used as a final filler for the top course. Make sure to compact any soil very well— this is best done when soil is moist.

Other Uses of Rock in Trail Work

Rigging for rock transport is best covered in an advanced class or project. This class is for basic work with readily available tools. Note also that we do not emphasize overlapping solid rock staircase construction in this curriculum, because the PCT is a horse trail, so rock steps should be minimized.

Rock Checks: Rock checks also known as check steps or rock riser steps, can be effective triage for gullied tread. Waterbars and dips can't divert water from the trail if the trail follows the ***fall line***. In such cases, checks are simply a means to harden or ***armor*** the tread and slow further erosion. For more about checks, see Course 203 or 205.

Guide Rocks: In cases of braided tread, widened tread, or ***tread creep***, it is useful to install ***guide features*** at irregular intervals along the outside edge of the trail to encourage users to move to the middle of the trail. Large angular rocks can make good guide features, if they are well-embedded so they won't be rolled out. These are sometimes called gargoyles or dummy rocks. If no rocks are available, another possible guide feature is a large log moved in perpendicular to the trail, just touching the outside edge (NOT parallel to the tread, which blocks drainage). If tread creep is the problem, guide features should be installed only after addressing the slough or brush on the uphill side that's pushing users out.

Guide features are also important finishing touches to any trail structure, whether it is a check step, drain dip, waterbar, drainage crossing, turnpike, switchback corner, or retaining wall. After completing any trail structure, step well back, and assess whether trail users (especially horses) might be tempted to bypass it. When users go around tread structures, water and erosion are sure to follow.

Rock Armoring: If no rock walls are needed, consider having students install rock armoring on a section of eroding, steep trail instead. Of course, you'll still need to divert the water uphill from the damaged tread, if water is the primary cause of erosion. Armoring creates a solid dry tread by installing tightly fitted rocks (preferably large). Techniques include variations upon paving (rocks set flat) and pitching (rocks buried on edge). (see Trail Solutions reference and link below for details of rock armoring).

Drainage Crossings and Fords: These require special rock armoring techniques, see Course 207.

TEACHING TIPS & TECHNIQUES

Quality Work:
Walk the trail and point out what conditions call for rock walls and guide rocks. Then give each student a couple pin flags and ask them to mark a candidate location for a rock wall and guide rock. Have them describe why they chose their locations.

Have students work in teams of two to four to collect, transport and build at least one tier of a successful rock wall. Also have each team locate a place on the trail where a guide rock is needed, and set one. If time allows, or if space is too tight at the rock wall, have teams work on a section of tread that needs rock armoring or rock checks, or perhaps a switchback that could use riprap.

Figure 4. Calculated rock weights. (IMAGE COURTESY OF VOC)

ROCK DIMENSIONS (in inches)	GRANITE, BASALT, LIMESTONE (weight in pounds)	SANDSTONE (weight in pounds)
6 x 8 x12	57	47
6 x 10 x 12	71	58
6 x 12 x 18	128	105
8 x 10 x 12	95	78
8 x 12 x 18	170	140
8 x 12 x 24	226	187
10 x 10 x 10	98	81
10 x 10 x 12	118	97
10 x 12 x 18	212	175
12 x 12 x 18	255	210
12 x 12 x 12	170	140
12 x 18 x 18	383	314
12 x 18 x 24	510	420
12 x 18 x 36	765	629
12 x 24 x 24	680	560
24 x 24 x 24	1360	1120
24 x 36 x36	3060	2519
24 x 36 x 48	4080	3359

Supervise closely to be sure that rocks are large enough and of an appropriate shape. Encourage students to find and flag a few candidate rocks and have an instructor evaluate them before they are transported to the trail. Use a similar approach to construction of the wall itself. It is essential that students do good rock work, or they will be wasting their own and future crews' time. A poorly build rock wall may only take an hour or two to build, but it might not last even a few years. A well built wall may take a day or more to build, but should last a lifetime. Surely an extra few hours is worth that extended life.

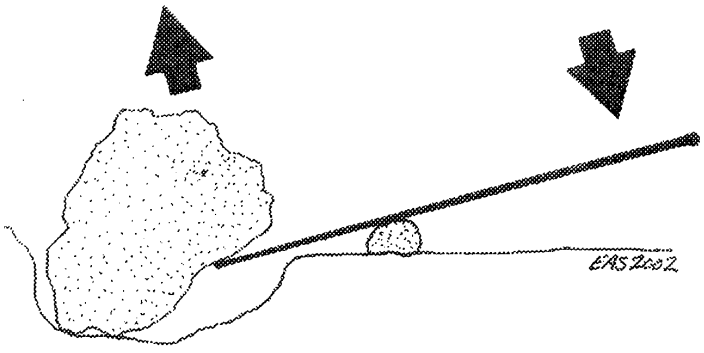
Ask students to redo their work if it is unsatisfactory, though try to catch it early to minimize frustration. Remember the test for every rock placement: dance a jig on it and be sure it does not move AT ALL.

Rock work, of course, is not everyone's cup of tea. If someone in your group has no aptitude or interest in such heavy and exacting work, assign them to collecting small rocks and making crush, or bringing in mineral soil. They might be good at fitting small rocks tightly around larger rocks or meticulously packing dirt. The key is to find the right job for each person.

Of course, demonstrate the proper stance and technique for each of the tools and rock moving to minimize body strain.

Stress the importance of doing everything slowly and carefully with rock, to avoid injuries.

Figure 5. Using a small rock as a fulcrum with a rock bar to lift a larger rock. (IMAGE COURTESY OF VOC)



Rock Shopping: look uphill or along the sidehill -- only downhill if you have a rock carrier or rigging. See Maxims. To avoid disturbing habitat, don't remove rocks from sensitive streams. To avoid eyesores, don't remove rocks from right next to the trail, unless you can do a very good job disguising the hole. The main thing is that rocks need to be big and well shaped, and that it often takes patience and persistence to find and transport the right ones. Let students know it is common

to spend as much (or more) time quarrying as building.

Ask each student to estimate the weight of the rock they have chosen, given that granite, basalt and limestone weigh about 175#/cu.ft, and sandstone 145#/cu.ft. See http://www.reade.com/Particle_Briefings/spec_gra2.html#W for weights of various materials.

Rockbars & Moving Rock: The rocks needed to do quality rock work should be too big to lift safely, even with two people. Thus it is essential for rock workers to learn how to move rock without straining for smashing body parts. If you have time, start the day in an open area, such as a trailhead, demonstrating and having students practice lifting and ***rowing rocks*** using rock bars and rock carriers.

Figure 6. To move a large or awkward buried rock, first dig the soil out around it. Next, use rock bars with stone fulcrums to lift the rick up, while simultaneously filling the hole in with smaller stones. Eventually, the rock will be lifted out of the hole but the addition of the fill and it can then be moved out of the way easily. (IMAGE COURTESY OF VOC)

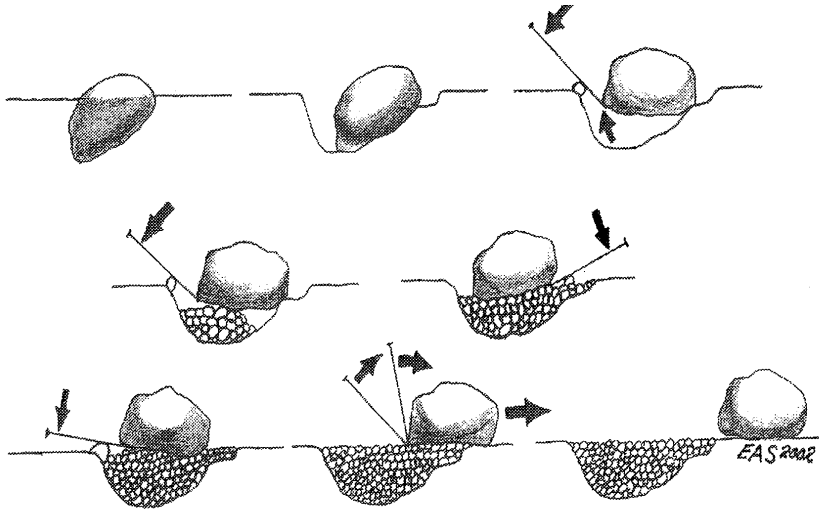
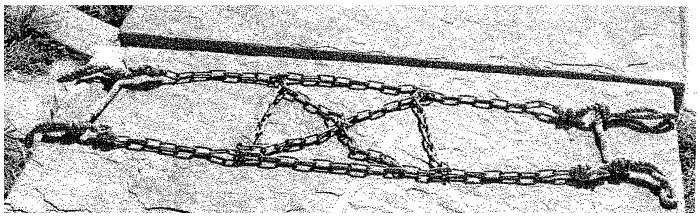


Figure 7. Austin rock sling. (IMAGE COURTESY OF VOC)



Demonstrate principles of ***mechanical advantage***, specifically how placement of fulcrums changes the advantage of rock bars. Using a tape measure show how advantage varies from 2:1 to 3:1 etc., based on relative position of the fulcrum and distance the bar handle moves versus the rock. Stress the importance of a stable fulcrum to avoid sudden slips that can cause neck whiplash. Have them experiment with log versus rock fulcrums.

Make sure students learn how to remove a large buried rock by lifting it slowly with bars and then inserting smaller rocks under it. Never place hands under a raised rock--use a tool handle. Repeat until the rock rises out of the hole. Or, if the goal is to simply move a giant rock out of the way, dig a deeper hole off to the side, and lever the rock into it.

If rocks are being skidded or carefully rolled down a steep hill, make sure the area below is cleared of people. Trail workers have been killed by runaway rocks. Remember, if a rock gets away, SHOUT “ROCK!” so all can hear.

Demonstrate bumping rocks with a vertical bar for small horizontal rock adjustments.

Tool Care: Be sure to stress the difference between rock and digging/tamping bars, and how easy it is to bend the latter if inappropriately using one for levering rocks.

Demonstrate proper use of a rock stretcher, boulder sling or Austin rock sling, if you have one. At the very least let them know such things exist and where they can buy them. Trail Services, Inc. (www.trailservices.com) sells nice boulder slings. A wheel barrow or hand truck is an option outside of wilderness areas, if not too far from the trailhead.

TRAIL FUN

For a fun wrap-up do a fast-paced “Jeopardy”-style quiz based on the KEY CONCEPTS.

Consider having a large “rock race” between two teams of two, to practice rock rowing.

REFERENCES

Lightly on the Land: The SCA Trail Building and Maintenance Manual. 2005. Robert Birkby. The Student Conservation Association and Mountaineers Books. Chapter 13, pp 185-198 is “Building with Rock”; pages 161-174 covers rock drainage structures.

OSI Trail Skill Series. Outdoor Stewardship Institute, a program of Volunteers for Outdoor Colorado. 2009. Based in Colorado, VOC specializes in rock work and has developed excellent materials. www.voc.org

Trail Construction and Maintenance Notebook. 2007. Woody Hesselbarth. USDA Forest Service. This can be viewed in entirety at http://www.fhwa.dot.gov/environment/fspubs/07232806/index.htm See especially sections on “Tread Creep” for guide rocks p. 66-67; “Switchbacks” p.106-108; “Retaining Walls” p.111-114; and “Check Dams” p.138-140. A free copy can be ordered at: http://www.fhwa.dot.gov/environment/rectrails/trailpub.htm

Trail Solutions: IMBA’s Guide to Building Sweet Singletrack. 2004. An excellent book on rock work (p.159-182) IMBA (International Mountain Biking Association) also has some online resources such as http://www.imba.com/resources/trail_building/rock_armoring.html While the PCT is not open to bikes, many of the rock techniques needed to stand up to horses are the similar.

PCTA Trail Skills College Curriculum

Field Reference

Course 300. Rock Retaining Walls

STUDENT SKILL OUTCOMES:

- Understanding of ideal rock size & shapes for rock structures.
- Safe quarrying and transport of rock, especially safe use of rock bars.
- Construction of effective rock walls from one to three tiers.
- If time allows, side projects include installing guide rocks, rip rap, and other minor trail armoring.

KEY TERMS:

Batter: the inward slope of the outside face of a rock wall. Expressed as a ratio of rise to run, as in 3:1, meaning 3 inches or feet of rise to 1 inch or feet of run. Such batter helps stabilize a rock wall.

Cap Rock: the top tier of large stones on a constructed rock wall. Must be large and stable enough to withstand horse traffic. An irregular top is ideal to encourage trail users to stay away from the edge.

Foundation Rock: very large base stones of a constructed rock wall, all set on a solid inlsoped base. Flat on top and insloped for next tier of rocks. Ideally the lowest one is held in place by bedrock a solid boulder.

Guide Rocks: (aka dummy rocks) large rocks buried solidly on the outside edge of tread on a steep side slope can keep horses to the middle of the tread, preventing them from collapsing the outside edge.

Mechanical Advantage: in essence, the multiplication of ones strength by using simple machines such as levers (rock bars), inclined planes (wedges) and pulleys (blocks & tackle). Most trail tools, such as a pick mattock for example, are combinations of levers (the handle) and wedges (the pick and mattock).

Mineral Soil: dirt than includes little or no organic material, ideal for trail tread and fill.

Riprap: (aka scree or junk wall) medium to large angular rocks loosely (or ideally carefully) stacked on an unstable slope to slow erosion. In trail work, riprap may be placed adjacent to steps or check dams on the sides of ***gullied tread***, or to stabilize tread ***backslope*** or downslope. In some locales, riprap instead refers to ***rock armoring*** of tread.

Rock Armoring: (some places aka riprap) creating a solid dry tread by installing tightly-fitted rocks (preferably large). Various techniques include: flagstone paving, stone pitching, boulder causeway.

Rock Crush: small pieces of angular rock (essentially gravel) created by smashing larger rocks with a sledge. Used for fill around rock placements to stabilize them. Small angular rocks can also be collected if readily available. Round rocks and gravel act as ball bearings and thus are unacceptable for rock work.

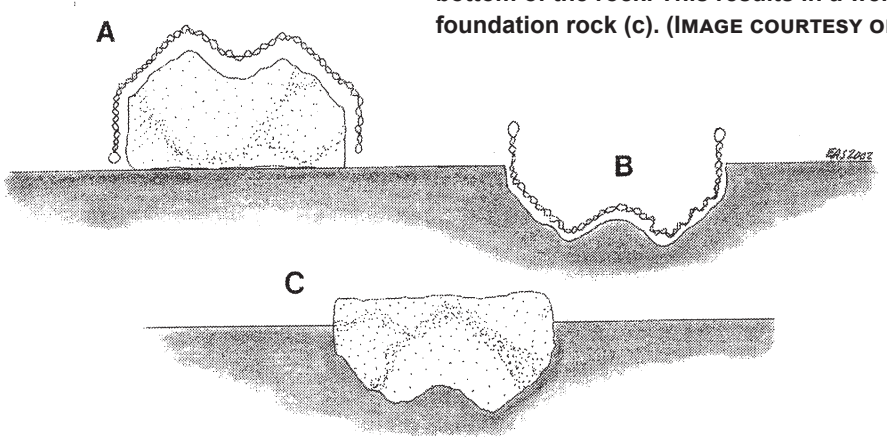


Figure 1. Using a length of malleable wire molded over a rock (a), will allow you to dig the foundation hole (b) to match the irregular bottom of the rock. This results in a well-seated and stable foundation rock (c). (IMAGE COURTESY OF VOC)

Rock Shopping: the thorough search for quality rocks for construction for walls, water bars, checks, etc. Generally the search is uphill or across the side slope, for ease of transport, since quality rocks will be larger than one person can carry.

Rowing Rocks: the lateral swing of a rock bar over a fulcrum to adjust a large rock sideways.

KEY CONCEPTS:

1) Safety Documents and Concerns:
   - Personal Protective Equipment (PPE), Job Hazard Analysis (JHA), Tailgate Safety Session (TSS), Emergency Action Plan (EAP)
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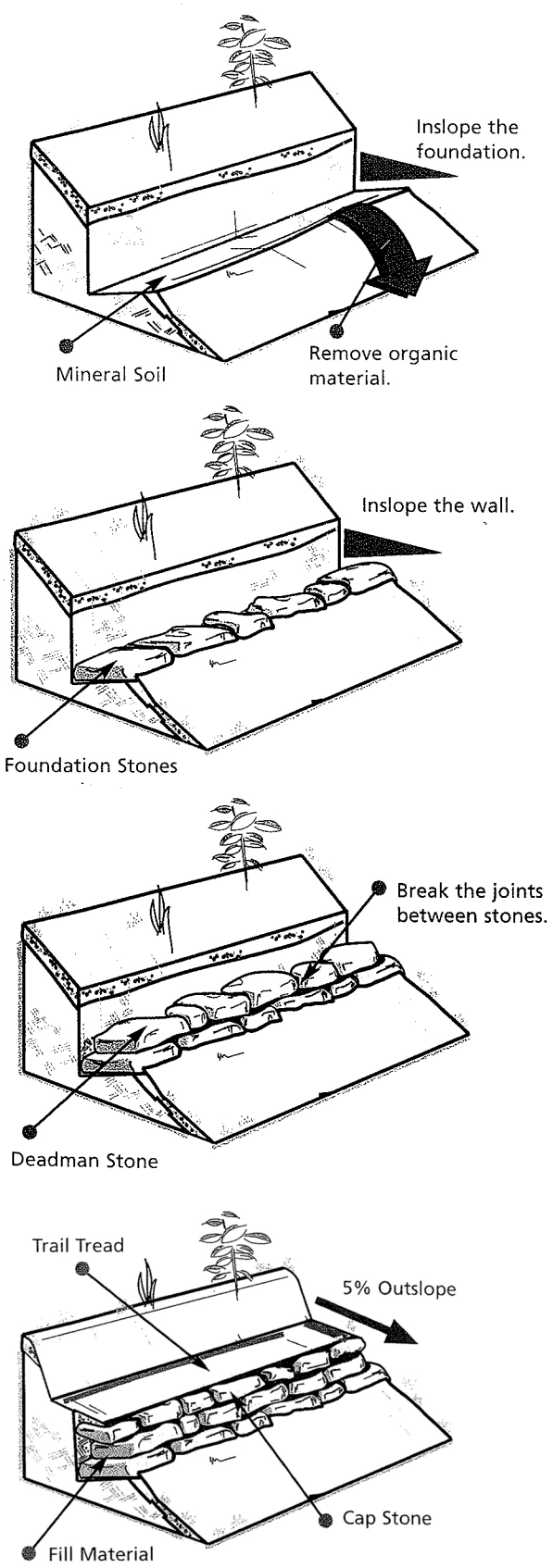
Figure 2. Step to constructing a rock retaining wall. (IMAGE COURTESY OF IMBA)



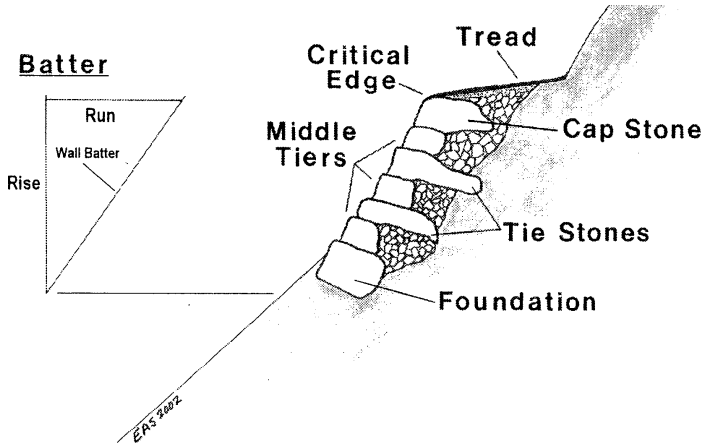


Figure 3. Side view of a wall illustrating the different elements if the structure. This wall and the hillslope have been drawn at an exaggerated angle to help illustrate the concept of batter (run over rise). The batter here is almost 1:1 but it would actually be about 1:4 for most walls. (IMAGE COURTESY OF VOC)

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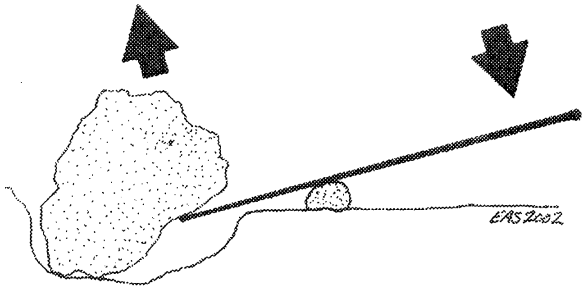
Figure 5. Using a small rock as a fulcrum with a rock bar to lift a larger rock. (IMAGE COURTESY OF VOC)



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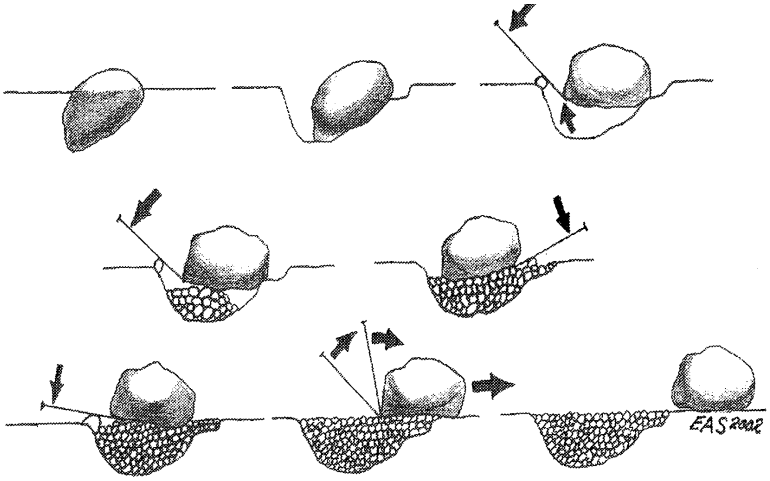

Figure 7. Austin rock sling. (IMAGE COURTESY OF VOC)