"The object of your mission is to explore the Missouri river, & such principal stream of it, as, by it's course & communication with the water of the Pacific ocean may offer the most direct & practicable water communication across this continent, for the purposes of commerce.

***. . .** Other objects worthy of notice will be; the soil & face of the country **. . .** the animals...the remains or accounts of any which may be deemed . . . extinct; the mineral productions of every kind; but more particularly metals, limestone, pit coal, & saltpetre, salines & mineral waters, noting the temperature of the last, & such circumstances"*

Excerpt from instructions written by President Thomas Jefferson to Meriwether Lewis, June 20, 1803

William Clark

by

Charles Willson Peale
from life,
1807-1808

Photo courtesy of the National Park Service

The Science of Geology and Lewis and Clark in the early 1800s

The science of Geology was in its infancy at the time of the Lewis and Clark Expedition. Neither Lewis nor Clark had any training in geology, mining, or mineralogy. The geologic terms they used, however, reveal much about their understanding (and misunderstanding) of geology. Their journal entries name several rock types: chalk, flint, flintstone, freestone, granite, lava, limestone, marble, marl, pumicestone, sandstone, sandrock, slate, slate stone, and slate rock. Generally, the captains identified these rock types correctly – but not always. The captains were acquainted with names of many minerals, nevertheless most of the minerals and salts that they described were identified incorrectly.

Lewis and Clark sometimes ascribed colors to rocks that probably resulted from conditions of sunlight, shadow or vegetation rather than to actual color of the rocks themselves. Both captains had a good command of geographic terms and used most of them in their current meaning. Both also seemed to have had some concept of geologic time because they occasionally used the phrase, "in some former age" when referring to river changes and certain geographic features.

Both Lewis and Clark had more of an understanding of stream erosion and deposition than did most people of the time, and the geologic observations they made during the expedition were among the finest of the day in America

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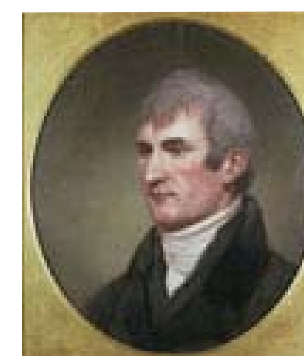
Little information has reached the public detailing the geography, geology, minerals or fossils that Lewis and Clark described in their journals. These pages depict and explain some of the more important geological observations and navigational aspects that the expedition recorded while within the present state of Montana.

Text by Bob Bergantino and Ginette Abdo; images as cited; graphics by Susan Smith; Web adaptation by Nancy Favero.

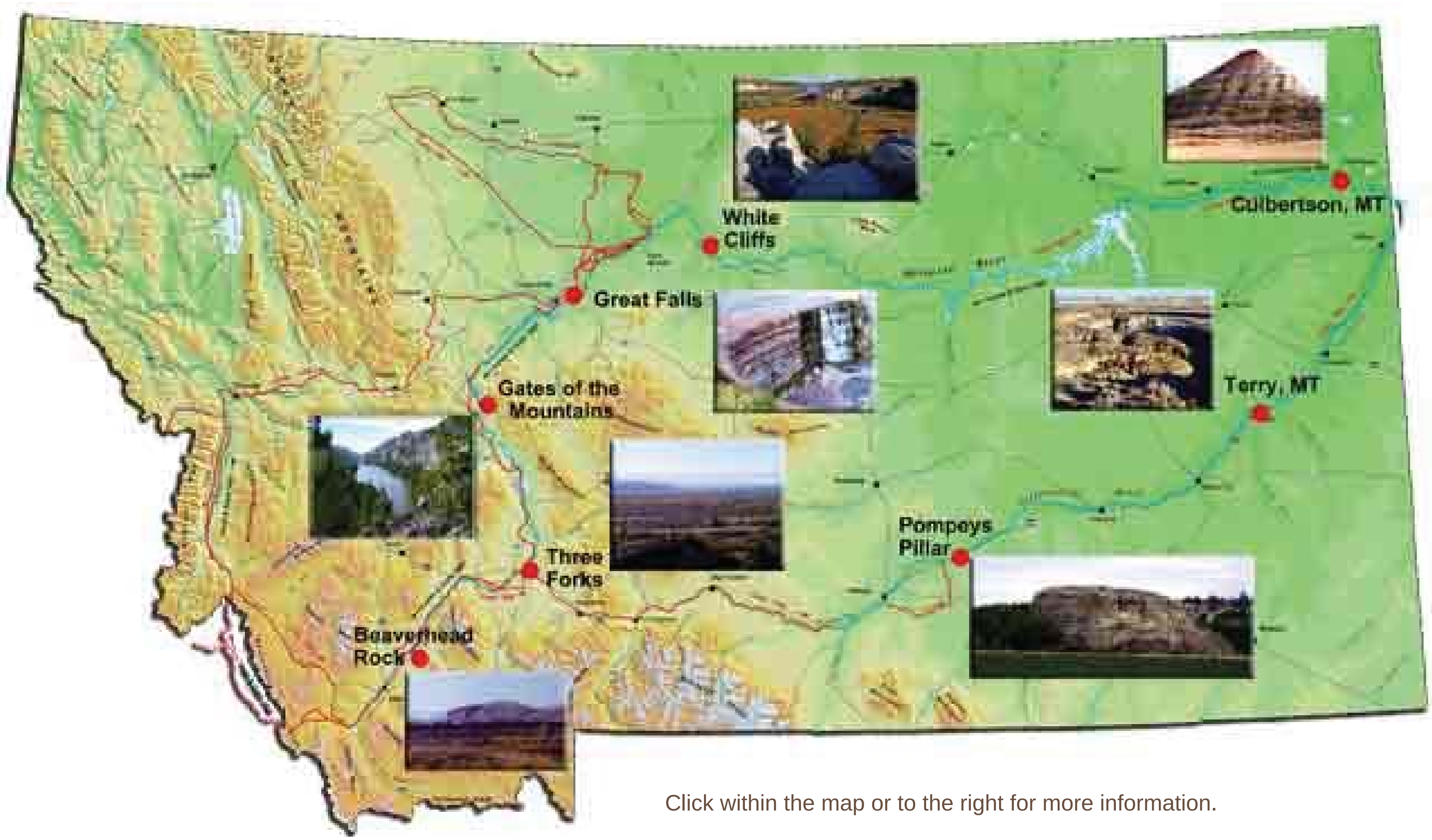


Meriwether Lewis

by

Charles Willson Peale
from life,
1807-1808

Photo courtesy of the National Park Service



Navigation

Equipment

Culbertson

White Cliffs

Great Falls

Gates of the Mountains

Three Forks

Beaverhead Rock

Pompeys Pillar

Terry

Click within the map or to the right for more information.

On their way....

The Lewis and Clark Expedition started up the Missouri on May 14, 1804. Theirs was a scientific mission—to discover what they could about the upper Missouri and a connecting route from its headwaters to the Pacific. Along the way, Lewis and Clark took and recorded magnetic bearings of the river's course, estimating the distance of each course. They also recorded aspects of the climate, geography and geology. By the time the expedition reached what is now Montana (April 27, 1805), it had logged more than 1900 river miles. The expedition exited Montana on September 13, 1805 at Lolo Pass and re-entered Montana at that same pass on June 29, 1806. By August 3, 1806 Clark had reached Montana's eastern border. Lewis passed that border on August 7

Photo courtesy of American Philosophical Society

A record of their observations

Lewis and Clark and several of the enlisted men kept journals in which they recorded the events of the day and their observations. The captains' journals were published in 1814, but most of the geological, botanical and navigational entries were deleted. When the original manuscript journals of Captains' Lewis and Clark were rediscovered in the early 1890s and published in 1904-05, ew interest developed in the expedition.

Since 1905, additional original materials have been discovered, and interest remains strong as the spirit of the expedition continues through the present day. The first description of Lewis and Clark's geological observations begins on April 28, 1805.

Navigation — finding the latitude

Three Forks of the Missouri, July 27, 1805 :

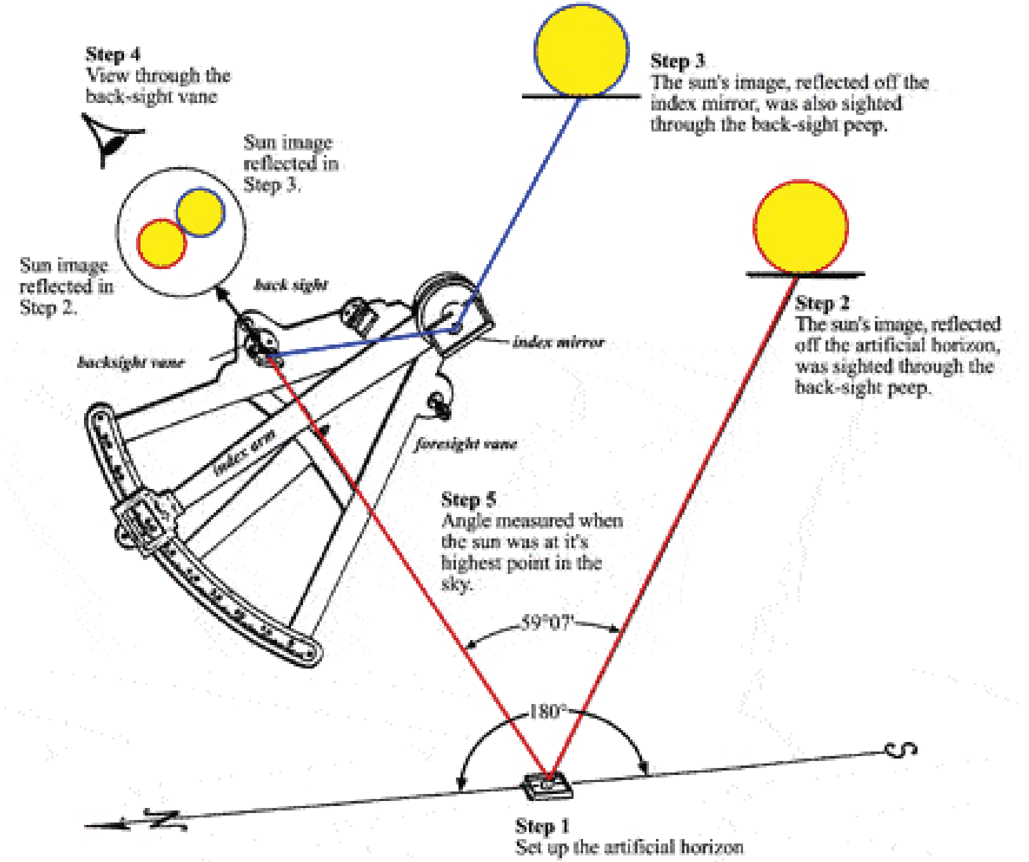
> *. . . believing this to be an essential point in the geography if this western part of the Continent I determined to remain at all events untill I had obtained the necesary data for fixing it's latitude Longitude &c.*

Until the latter part of the 20th Century, the most common observational method to find one's latitude was to use a sextant or octant and take a noon shot of the sun. The noon shot was preferred because 1) an accurate timepiece was not necessary and 2) an observation taken when the sun is due north or south (that is, on the observer's meridian) greatly simplifies the calculations (see Part II, below).

Let's use Lewis's observation at the Three Forks to show how the captains made their observations and calculations to determine latitude.

Part I, Using the Octant to take the observation

When the sun's noon altitude was greater than 60° (April - September) Lewis and Clark used their octant, which was equipped for the back-sight method (see Equipment). Using the back-sight method, their octant theoretically could measure an angle between two objects up to 180°.



Taking a noon observation with the octant and artificial lorion by the "back" method.

1. Shortly before noon on July 29, 1805. Lewis prepares to take an observation of the sun for latitude. Because mountains to the south rise above the natural horizon, Lewis prepares an artificial horizon using a tray filled with water; the water will form a level surface and reflect the sun's image to his eye.

2. Lewis places his eye to the octant's back-sight vane. He then looks through a slit in the back-sight horizon glass and finds the image of the sun reflected from the water in the tray.

3. While still sighting the sun's image reflected from the water, Lewis moves the octant's index arm with its index mirror until the sun's image is reflected from the index mirror to the back-sight horizon mirror and then to his eye. Because Lewis wants to obtain the altitude of the sun's lower limb he brings the two images together so that the bottom of the sun's image reflected from the index mirror just touches the top of the sun's image reflected from the water.

4. As the sun continues to move toward its highest point in the sky for the day (noon), the two images of the sun overlap. To keep the two images in contact at a single point, Lewis turns the tangent screw on the octant's index arm, gradually decreasing the angle measured by the index arm.

5. Lewis keeps the two images just touching each other. When the two images stop overlapping, Lewis knows that the sun has reached it highest point in the sky. The images remain just touching each other for ten seconds or so, then begin to separate as the sun slowly descends. Lewis, however, already has clamped the index arm in place and, with the help of the vernier, reads the angle on the graduated arc as indicated by the zero mark on the index arm. That angle is 59°07'.

Part II, Applying the Corrections to the Angle Lewis Measured

The angle that Lewis measured during this noon shot is not the altitude of the sun's center but: 180° minus 2x the altitude of the sun's lower limb. The angle he measured also includes angles caused by mirror misalignment (index error), refraction (see Step D), parallax (see Step E), sun's semidiameter (the angle between the sun's lower limb and its center — see Step F) and the sun's declination (angular distance north or south of the equator — see Step G). All these angles have to be eliminated in order to derive the true altitude of the sun's center with respect to the earth's center.

The first step in making corrections to the observed angle usually is to subtract the index error (or in some manuals, apply the index correction) but . . .

A) Lewis first divides the angle he measured by 2

Because Lewis had to measure the angle between the ray reflected from the index mirror and that from the artificial horizon, the observed angle is twice that from a natural horizon alone.

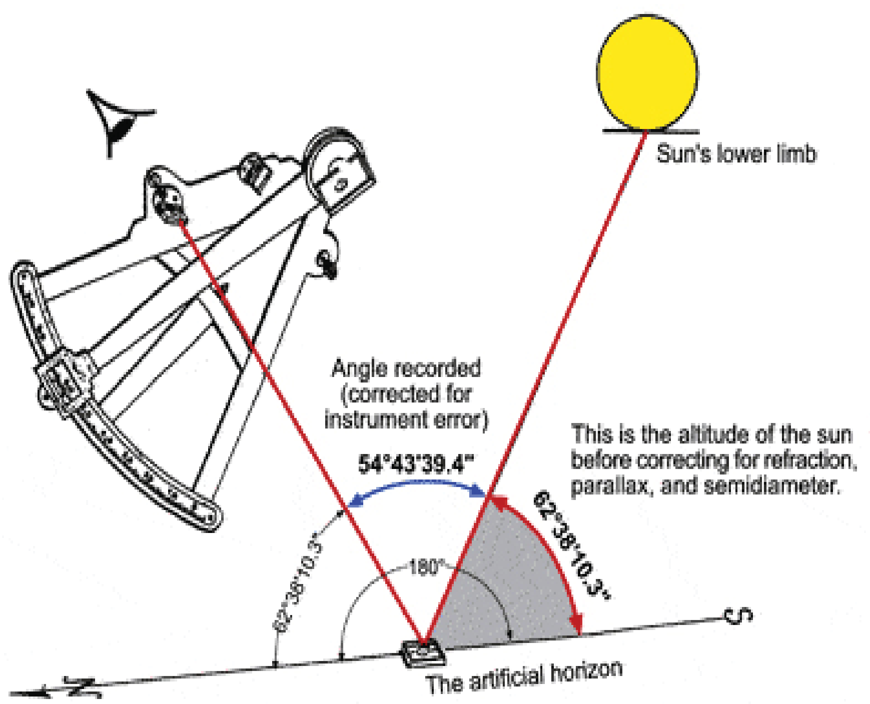
59°07'
÷ 2
29°33'30"

B) Then he subtracts the result of Step A from 90°

Since Lewis already has divided the observed angle by 2 in Step A, he must subtract that result from 90°, not 180°.

90°00'00"
- 29°33'30"
60°26'30"

C) Next Lewis adds half the OCTANT'S INDEX ERROR



Lewis, in his journal for July 22, 1804, recorded that the octant's index error in the "back-method" was +2°11'40.3". The octant's index error actually was +4°23'20.6"; that is, it read too high by that amount. Lewis,however,began his corrections by dividing his measured angle by 2 and, thus, needed to apply only half the index error (though still calling it"index error"). Because Lewis's octant read high the indexerror should be subtracted, but owing to the sequence Lewis used to make his corrections, he needs to add 2°11'40.3" to the result of Step B.

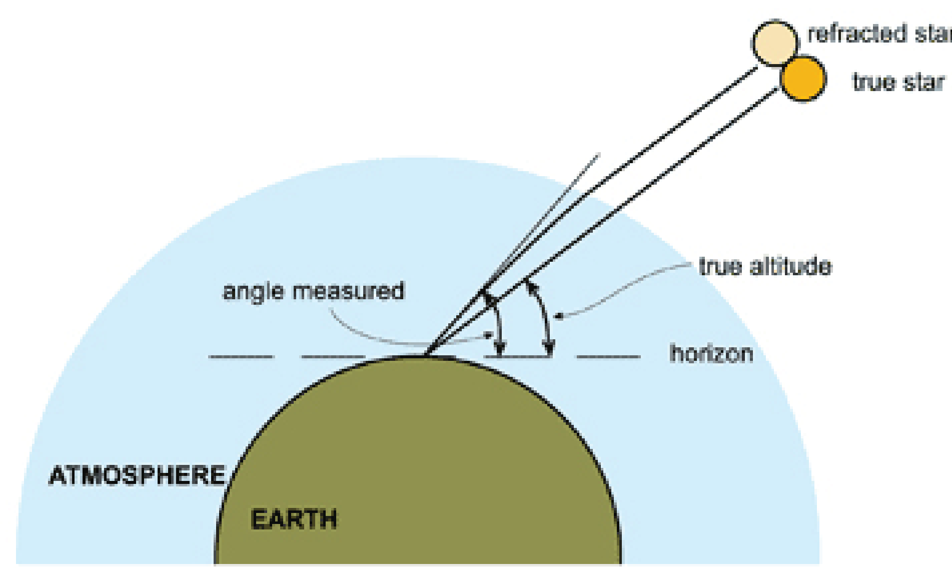
60°26'30"
+ 2°11'40.3"
62°38'10.3" = 62°38'10" = apparent altitude of sun'slower limb

Note: Although the octant's index error by Lewis's method was +2°11'40.3", he mistakenly used an index error of +2°40" throughout 1805. He discovered this mistake while at Fort Clatsop on the Pacific Coast. Using the wrong index error made the latitude he calculated on July 29 too far south by about 0°28'20" or about 32½ miles. The calculations here are made as if he had used the correct index error.

D) Then he makes the correction for REFRACTION

Lewis opens his book Tables Requisite to the table "Mean Refraction" and, using the altitude derived from Step C, he finds that he has to subtract 24".

62°38'10" apparent altitude of sun's lower limb
- 0°00'24" refraction correction
62°37'46" apparent altitude of sun's lower limb corrected for refraction



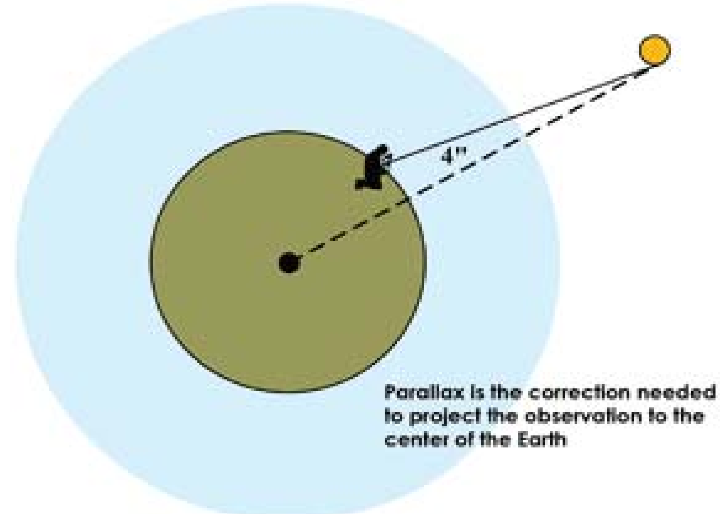
Refraction is the bending of a light ray as it passes through the atmosphere. This bending results from the increase in the atmosphere's density as the light ray travels downward toward the observer.

Refraction makes an object appear higher in the sky than it actually is.

The light ray always appears to be bent upwards except when it is vertical, therefore, Lewis subtracted 24" from the apparent altitude found in Step C.

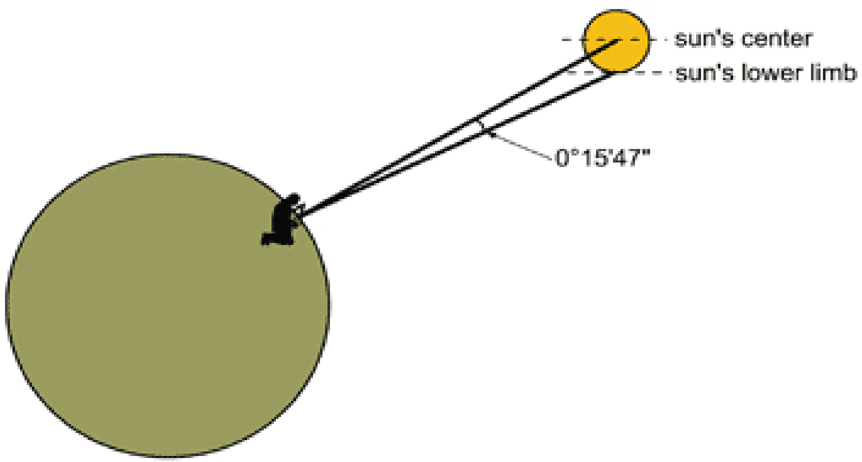
E) Lewis then makes the correction for PARALLAX

The latitude that Lewis is calculating must be measured from the center of the earth. Lewis again goes to his *Tables Requisite*, opens it to the table “Parallax of the Sun in Altitude”, and, using the apparent altitude of the sun’s lower limb from Step C, finds that he has to add 4”.



62°37’46” altitude of lower limb corrected for refraction
+ 0°00’04” parallax correction
62°37’50” sun’s lower limb projected to the center of the earth

F) . . . adds the SUN’S SEMIDIAMETER



It is usually easier for an observer to find either the upper or lower limb of the sun rather than its center. Lewis, when using the octant, always shot the sun’s lower limb. The angular difference between the sun’s center and its upper or lower limb is called its “semidiameter” (half diameter). The Nautical Almanac Lewis used had a table giving the sun’s semidiameter at Greenwich noon for the 1st, 7th, 13th, 19th and 25th of each month. For July 25, 1805 it was 15’46.7” and on August 1 it was 15’47.5” For his observation on July 29, Lewis determines a semidiameter of 15’47”. He adds this to the result of Step E to find the true altitude of its center because he shot the sun’s lower limb.

62°37’50” altitude of lower limb projected to the center of the earth
+ 0°15’47” sun’s semidiameter
62°53’37” true altitude of the sun with respect to the earth’s center

G) . . . and subtracts the SUN’S DECLINATION

Now Lewis has the true altitude of the sun’s center above the horizon, but that altitude includes the sun’s north declination.

A celestial body’s declination is the number of degrees that body is north or south of the celestial equator at a given moment as “viewed” from the center of the earth. The declination of stars and distant planets changes slowly, but the sun’s declination changes by more than 23° between the equinoxes, stopping only for a brief interval at the solstices. From the spring equinox until the autumnal equinox the sun’s declination is North (+), the remainder of the year its declination is South (-).

The angle that Lewis has just measured includes the sun’s North declination. Therefore, he must subtract the sun’s declination from the result of Step F. If the declination had been south he would add it.

The Nautical Almanac for 1805 that Lewis carried, however, gave the sun’s declination only for noon of each day at Greenwich, England. Lewis, thus, has to determine what the sun’s changing declination would have been at the time of his observation. To do this he has to make a separate set of calculations.

How did Lewis determine the sun’s declination at the time of his observation?

a) Lewis looks in his Nautical Almanac for July. On page 74 in the column with the heading “Day of the Month” he finds 29 and following across to the right to the column with the heading “Declin. North” he finds .... 18°50’01” (July 29)
and for the 30th he finds .... -18°35’44” (July 30)
b) He subtracts the declination for July 30 from that for July 29 0°14’17”change per day
c) Then he divides that result by 24 to find the change in sun’s declination per hour ÷ 24
°0’35.7”change per hour

d) Now Lewis needs to know how many hours had elapsed between noon at Greenwich and noon at the Three Forks. The number of hours elapsed multiplied with the hourly rate gives the total change in declination since Greenwich noon. Lewis finds the number of hours elapsed by dividing his longitude by 15. He doesn't know his exact longitude, but he can estimate it or derive it by dead-reckoning. Lewis didn't save his calculations, so let's assume he used 111° West as his longitude:

111° ÷ 15 = 7 hours 24 minutes = 7.4 hours
7.4 hours x 35.7 arc seconds per hour = 0°04'24"

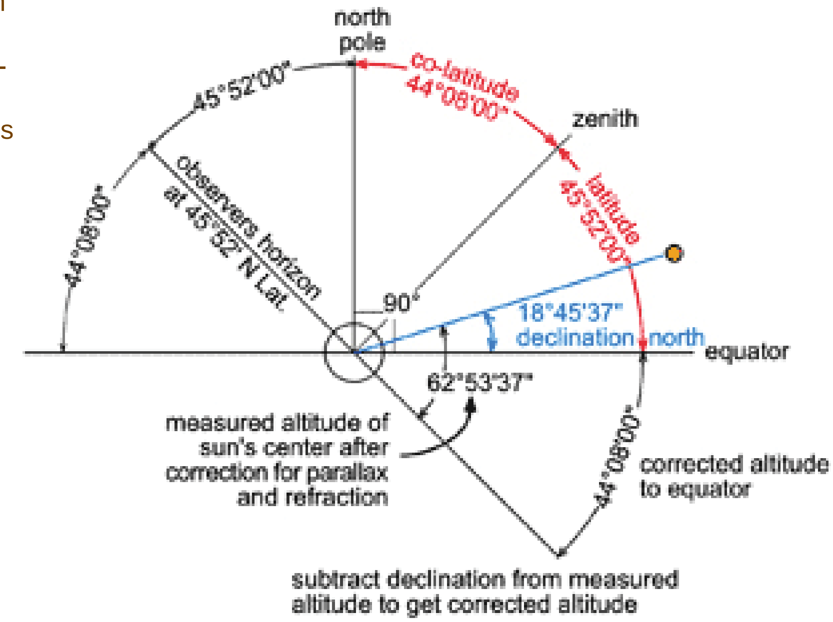
Therefore since Greenwich noon July 29 the sun's declination has decreased by 0°04'24".

e) Lewis subtracts this amount from the sun's noon declination

+18°50'01" declination Greenwich
 - 0°04'24" total change
+18°45'37" declination Three Forks

Finally, he subtracts the sun's declination from the result of Step F

 62°53'37" from Step F
-18°45'37" declination
 44°08'00" co-latitude



H) From co-latitude to latitude

Steps A through G produce what is called a "co-latitude". A co-latitude is the angle which, when added to the latitude equals 90°; that is

90° - co-latitude = latitude.

To derive the calculated latitude from this observation Lewis subtracts the co-latitude from 90°

90°00'00"	
- 44°08'00"	
45°52'00"	*LATITUDE*
45°52'	*Latitude to nearest arc minute per this observation (about 3 miles too far south)*
45°55½'	*Latitude of camp determined from map analysis*
45°23'23"	Lewis's calculated latitude using incorrect index error of 2°40' instead of2°11'40"

Expedition's Scientific Equipment

To Captain Meriwether Lewis esq. Capt. of the 1st regimt. of the Infantry of the U.S. of A

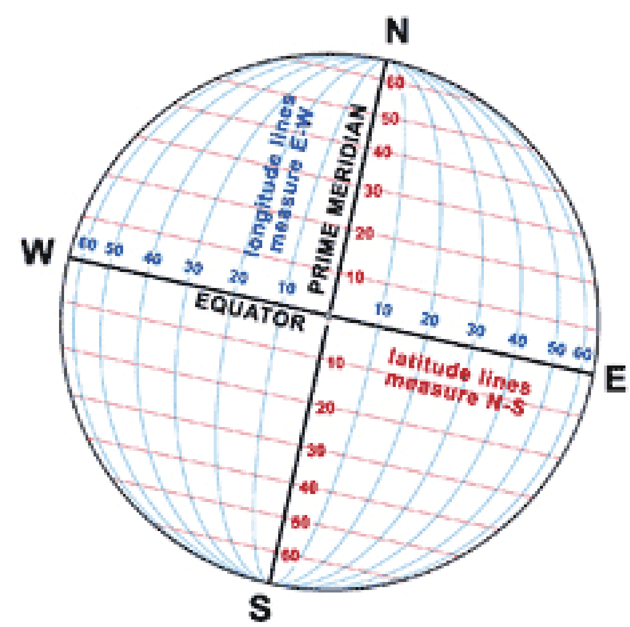
> *… The object of your mission is to explore the Missouri river, & such principal stream of it, as, by it's course and communication with the waters of the Pacific Ocean, whether the Columbia, Oregan, Colorado or any other river [which] may offer the most direct & practicable water communication across this continent for the purposes of commerce …*
>
> *Beginning at the mouth of the Missouri, you will take careful observations of latitude & longitude, at all remarkeable points on the river, … & other places & objects … that they may with certainty be recognised hereafter. The courses of the river between these points of observation may be supplied by the compass … the log-line & by time, corrected by the observations themselves. The variations of the compass too, in different places, should be noted …*
>
> *The interesting points of the portage between the heads of the Missouri, & of the water offering the best communication with the Pacific ocean, should also be fixed by observation, & the course of the water to the ocean, in the same manner as that of the Missouri…*
>
> *"Given under my hand at the city of Washington this 20th day of June 1803."*
> *[signed] Thomas Jefferson, President*

Thomas Jefferson envisioned the Lewis and Clark Expedition as a scientific expedition, but also hoped it would find a practical commercial route to the Pacific. Not only did Jefferson want the information that expedition obtained, he wanted an accurate map of the country through which it passed. To make an accurate map of such a large area would require accurate locations of river junctions, rapids, falls, mountain passes, and native settlements. Jefferson knew that such a map could not be made from a survey using just a magnetic compass and estimated distances. The solution — find the latitude and longitude of important points along the route and adjust the compass survey to them.

Latitude is the angular distance north or south of the equator. The latitude at the equator is 0°; at the poles it is 90°

Longitude is the angular distance east or west of the Prime Meridian (the north-south line through Greenwich, England); the longitude there is 0°. From the Prime Meridian the longitude increases eastward (east longitude) to 180° and also westward (west longitude) to 180°

The intersection of a parallel of latitude with a meridian line of longitude marks the location of a unique spot on the surface of the earth.



In the early 19th Century, latitude and longitude usually were determined from celestial observations taken with a sextant or octant and chronometer. Lewis purchased this equipment in 1803. He also received training in how to make celestial observations and calculate them. From this training Lewis taught William Clark. Clark already knew how to use a magnetic compass to survey and he had a talent for map drawing.

The expedition's route survey would be made with a magnetic compass. The captains, therefore, also needed to make observations to determine how many degrees the compass needle pointed away from true north (that is, the magnetic declination). The celestial observations the captains took would fix the latitude and longitude of important river junctions and, by knowing the magnetic declination, the survey made with the magnetic compass between those points could be corrected to true north. From this, a cartographer could produce an accurate map.

Shown below are the scientific instruments similar to the ones Lewis purchased in Philadelphia.
Accompanying each instrument is a brief description of its design and its use.

Octant Octants were used principally to determine latitude by measuring the angle between the sun and the horizon. The instrument had a simple "A" shape and its legs formed an angle of 45°, hence its name (from Latin octans = one-eighth). Because the octant's two-mirror system used the principle of reflection it could measure an angle of 90°, thus the instrument sometimes was also called a quadrant. Most were made of hard, tropical wood.

The index mirror was attached to the index arm usually 12 to 14 inches long. The fore-horizon glass (half mirror-half clear glass) was affixed to the leg nearest the reflecting surface of the index mirror. A peep site was located opposite the horizon glass on the other leg of the "A".

The octant that Lewis and Clark used was also equipped with a back-horizon peep sight and mirror. This allowed them to measure the altitude of the sun when it was greater than 60° above the horizon (early April until late August along their route.)

This octant, purchased in Philadelphia for $22, is similar to the one used by Lewis and Clark.

Sextant The sextant, invented about 1757, had the same "A-frame" configuration as the octant, but it's circular arc spanned an angle of 60°, that is, a sixth (Latin sextant) of a circle and its index arm usually was 9–10 inches long. With its two-mirror system the sextant could measure the angular distance between objects that were as much as about120° apart. The sextant was made of brass and had a telescope for sighting.

Lewis and Clark used the sextant to measure the angular distance between the moon and sun or a star for longitude. They also used it for latitude when the sun's noon altitude was less than 60°. Although the sextant could measure an angle of up to 120°, the captains could not use the sextant to find the altitude of the sun when it was greater than 60° above the horizon because they needed to use an artificial horizon, which doubled the angle to be measured .

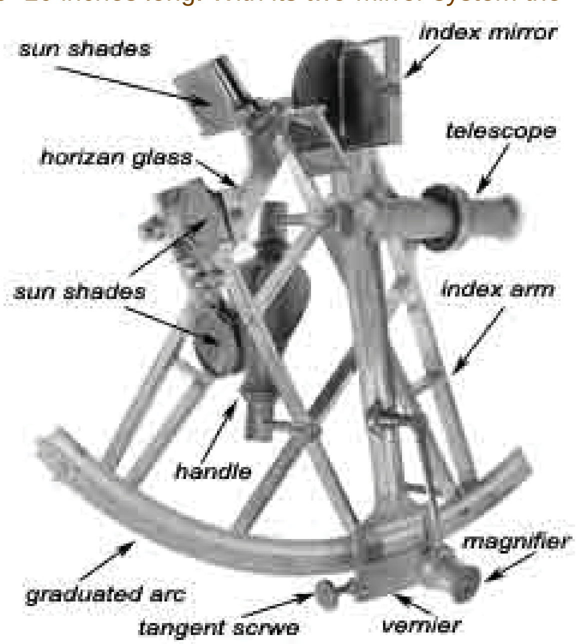


Photo courtesy of Smithsonian Institute

Chronometer A chronometer is a precise watch used to determine the time at which an observation is made. Chronometers usually are set to keep Greenwich Mean Time (the time at 0° longitude) because almost all nautical tables are based on Greenwich Time. Lewis and Clark's chronometer, however, showed Local Mean Time and, because it stopped on several occasions and ran erratically at others, they needed to make special observations of the sun to determine the true Local Mean Time.

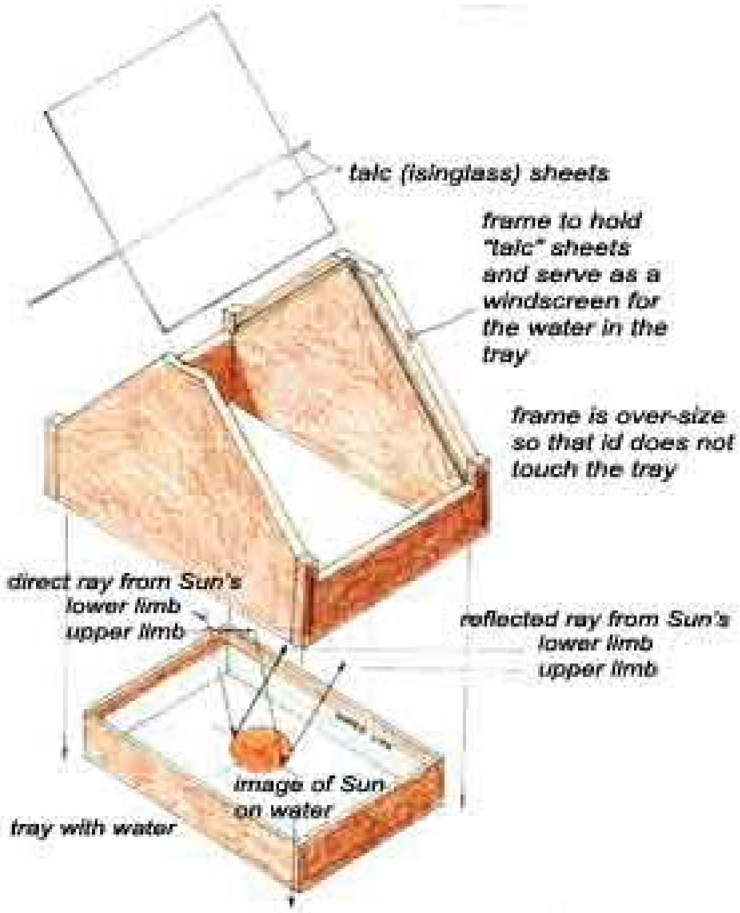
Checking the chronometer's time No chronometer kept perfect time; they either lost or gained time, though usually at a highly uniform rate. The captains knew that their chronometer lost time, but unlike most chronometers, its rate of loss was notconsistent. To determine the chronometer's error on Local Time, Lewis and Clark made observations called "Equal altitudes observations of the Sun."

Photo courtesy of Pieces of Time (www.antique-watch.com)

Using the sextant and artificial horizon, they would take three measurements of the altitude of the sun in the morning, noting the time shown by the chronometer for each. In the afternoon, when the sun was at the same altitude as it had been in the morning, the times again were recorded. The average of the times, after adjusting for sun's changing declination, gave the time that the chronometer would have shown at noon. The difference between this calculated time and 12 noon was the "error of the chronometer." From another Equal altitudes observation the next day or some days later, the captains could determine the chronometer's daily rate of loss during that period of time.

At a purchase price of $250 (plus 75 cents for a winding key), the chronometer was the single most expensive piece of scientific equipment taken on the journey.

"… her balance-wheel and escapement were on the most improved construction. She rested on her back, in a small case prepared for her, suspended by an universal joint, she was carefully wound up every day at "twelve o'clock." (Lewis, July 22, 1804)).



Drawing by Bob Bergantino, MBMG

Artificial Horizons Navigators at sea could determine the altitude of a celestial body by measuring the angle between it and the true horizon. Inland away from the sea or large body of water, however, one rarely has a true horizon. Therefore, on land, it generally is necessary to use an artificial horizon. Lewis and Clark carried three different types of them. Each design had its own advantages depending upon observing conditions

On bright days when the temperature was above freezing and the sun was being observed, Lewis and Clark commonly used a tray filled with water as an artificial horizon; the water made a level reflecting surface. The captains, however, used artificial horizons made from leveled mirrors when the temperature was below freezing. They also used them when observing stars because the image reflected from the mirrors was more distinct than from water.

Robert Patterson, a Philadelphia mathematician and astronomer, had devised several types of artificial horizons using either a regular (single-coated) mirror or the double-coated index mirror from a sextant. The mirror was cemented onto a wooden ball and the ball was set in a wooden frame and adjusted by three screws used as legs. It was leveled with the aid of a spirit level.

Pocket Compass Lewis purchased three pocket compasses for $2.50 each and also the compass shown in this picture. The pocket compasses were less cumbersome than the surveyor's compass and were used to take the bearings when impractical to use the circumferentor and when traveling on land.

This pocket compass was one of the few items that survived the journey. After the expedition returned to St. Louis, it was purchased by William Clark. The compass is on display at the Smithsonian Institution in Washington, D.C.

Photo courtesy of Smithsonian Institute

Surveyor's Compass or Circumferentor Lewis and Clark used the surveyor's compass to record their direction of travel and determine the bearing of celestial objects such as the sun and stars. Because the bearings they observed were based on magnetic north they often took observations of Polaris or the sun at the junction of major streams or other important points to determine the difference between magnetic north and true north. Most maps are based on true north which does not change through time or with location.

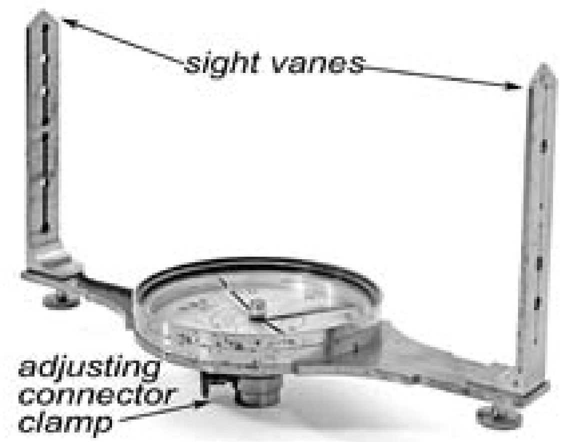


Photo courtesy of Smithsonian Institute

he circumferentor was simply a six-inch-diameter magnetic compass, but was much more precise than the usual pocket or hiking compass and could be read to one-half of a degree. The circumferentor was equipped with front and rear sight vanes to help improve the observer's ability to sight precisely on an object. On the underside of the compass housing was a receptacle to allow it to be fastened on a tripod or to a shaped pole that was placed firmly into the ground. Attached to that receptacle was a ball-and-socket joint that allowed the user to level the circumferentor with great accuracy. A spirit level would have been used in conjunction with the surveyors compass to establish a level plane from which to work.

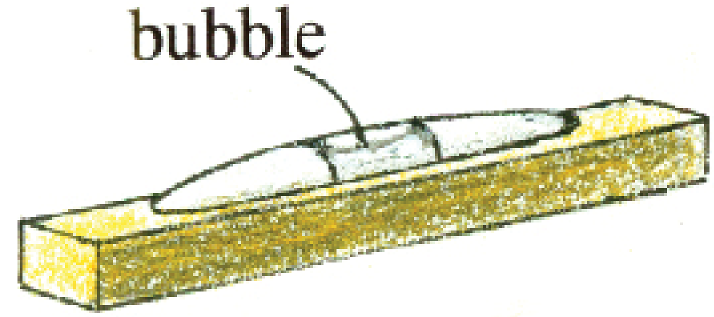
The circumferentor Lewis and Clark used was six inches in diameter and was divided into degree and half-degree increments.

Two-Pole Chain English and American landsurveyors of the 18th and early 19th century generally used a surveyor's chain constructed of iron links each 7.92 inches long.Surveying chains, called Gunters chains, normally were 66 feet long and were comprised of 100 links. Eighty Gunters chains equaled one statute mile and ten square chains (example: 5 chains x 2 chains) equaled one acre. A distance of 25 links (16½ feet) was called a "pole." Clark used the expedition's two-pole (50-link, 33-foot) chain primarily to measure a base line when determining a river's width by triangulation.

Two-pole chain similar to one used by Lewis and Clark.

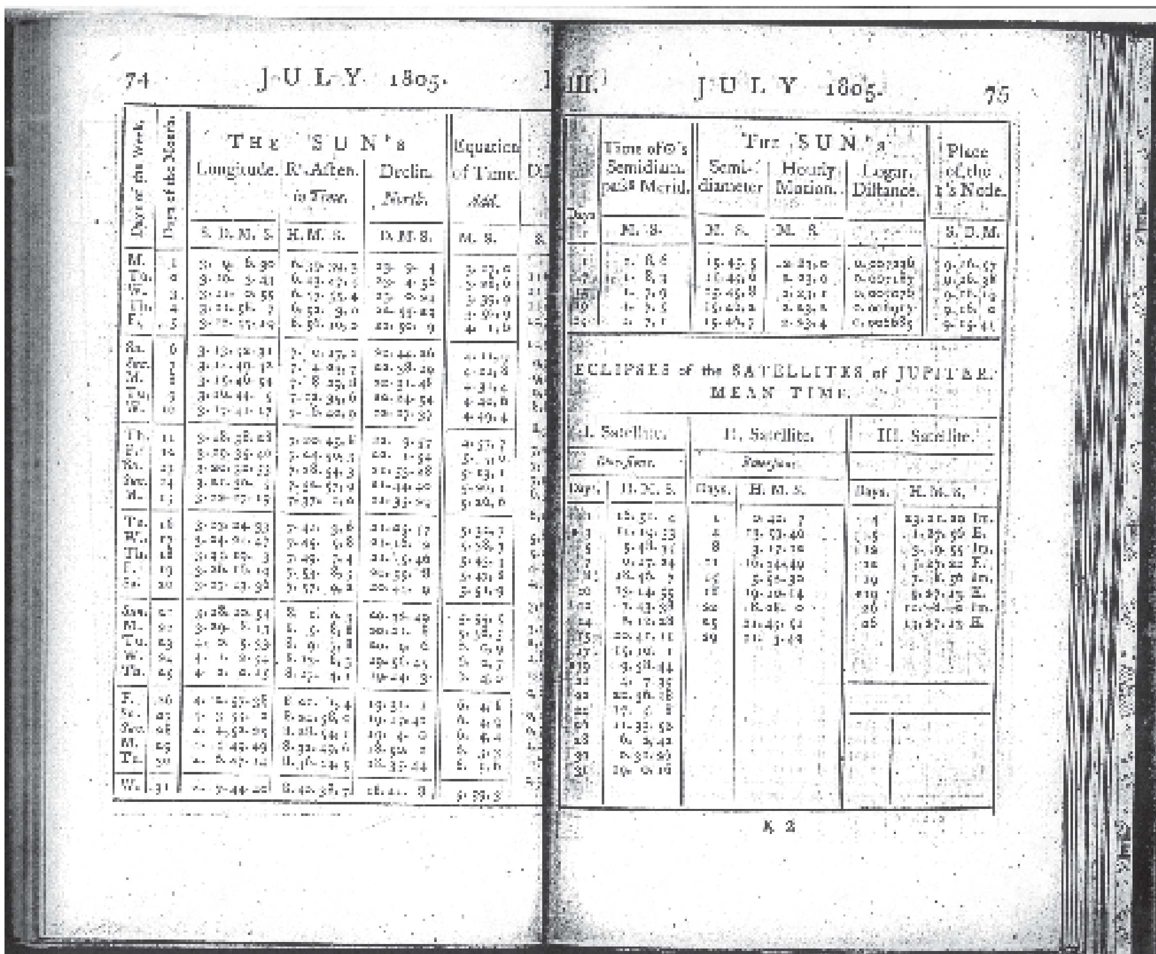
Image from The Theory and Practice of Surveying, 1911

Spirit Level A spirit level is similar to a miniature carpenter's level, though made with greater precision. It was used to level the surveying compass (circumferentor) for precise angular measurements and to level a mirror to produce an artificial horizon when water was not used. Clark also used the spirit level as a hand level when he measured the height of the falls and rapids of the Missouri from Lower Portage Camp to White Bear Islands (see Great Falls of the Missouri).



Drawing by Bob Bergantino, MBMG

Nautical Almanacs, Requisite Tables, Mathematical Tables The captains' celestial observations yielded nothing more than raw data. To determine latitude, longitude and-magnetic declination … their observations were processed with information provided by almanacs and tables


74 JULY 1805.

THE SUN's — Longitude. R. Ascen. in Time. Declin. North. — Equation of Time.

JULY 1805. 75

The SUN's — Time of ☉'s Semidiam. pass Merid. Semi-diameter. Hourly Motion. Logar. Distance. Place of the ☾'s Node.

ECLIPSES of the SATELLITES of JUPITER. MEAN TIME.

I. Satellite. II. Satellite. III. Satellite.

Lewis carried with him The Nautical Almanac and Astronomical Ephemeris … for the Year 1803, 1804 and 1805 (it is not certain that he had the 1806 almanac). The almanacs were published several years in advance of the year indicated on them and gave the celestial coordinates of the sun, moon, planets, and navigational stars at various increments of time at Greenwich, England.

A companion book to the Nautical Almanac was: Tables Requisite to be Used with the Nautical Ephemeris for Finding the Latitude and Longitude at Sea (Nevil Maskelyne). These books provided Lewis and Clark with valuable information on how and when to take observations, what corrections they needed to make to obtain valid results, and how to calculate geographic data from most of their observations. In addition, Lewis brought along a copy of A Practical Introduction to Spherics and Nautical Astronomy (Patrick Kelly) — a practical guide to spherical trigonometry and how to compute celestial observations and convert them into geographic information.

Image from The Nautical Almanac and Astronomical Ephemeris, 1805

Culbertson — entering Montana

Location Map

Despite near-freezing temperatures on the morning of April 27, 1805, Meriwether Lewis completed his celestial observations at the mouth of Yellowstone River. The Lewis and Clark Expedition then continued up the Missouri. Dangerous headwinds forced the canoes ashore about noon. At 4 pm the expedition continued upstream again, making camp just inside present-day Montana.

On April 28, Clark walked along the river bluffs:

> *. . . the hills & Bluffs Shew the Straturs of Coal, and burnt appearances in maney places, in and about them I could find no appearance of Pumice Stone . . . the Bluffs in this part as also below Shew different Straturs of Coal or carbonated wood, and "Coloured earth", such as dark brown, yellow a lightish brown, & dark red &c.*

The coal is lignite in the Tongue River Member of the Fort Union Formation. The "burnt appearances" likely refer to areas of clinker (local residents also call it scoria); clinker forms when a burning coalbed "bakes" adjacent shale and clayston

Lewis and Clark called any light-weight, frothy-looking rock with numerous pores or holes "pumice stone." Like clinker, it is produced when coalbeds burn, and is not of volcanic origin as the captains thought.

The "Coloured earths" were outcrops of siltstone, mudstone and soft sandstone in the Fort Union Formation.

Photos by Ginette Abdo, MBMG

Photo by Ginette Abdo, MBMG

Lewis, April 28, 1805

. . . the country through which we passed today is open as usual and very broken on both sides near the river hills, the bottoms are level fertile and partially covered with timber.

Later the 28th Lewis noted:

. . . the salts still increase in quantity; the banks of the river and sandbars are incrusted with it in many places and appear perfectly white as if covered with snow or frost.—

The captains had observed salt areas as far downstream as the Kansas River and had described “salines” (usually salt springs) in Missouri, Kansas and Nebraska. The quantity and extent of salt noted today far exceeded anything seen earlier.

Photos by Ginette Abdo, MBMG

This salt is not sodium chloride (common table salt) — but a variable combination of sodium, magnesium and calcium plus sulfate and bicarbonate. Ground water that passes through rocks and sediments dissolves some of the salts they contain. When that water returns to the surface (usually on a river shore or cliff face) and evaporates, salt crystals and crusts develop.

On April 29, Lewis opted to walk on shore:

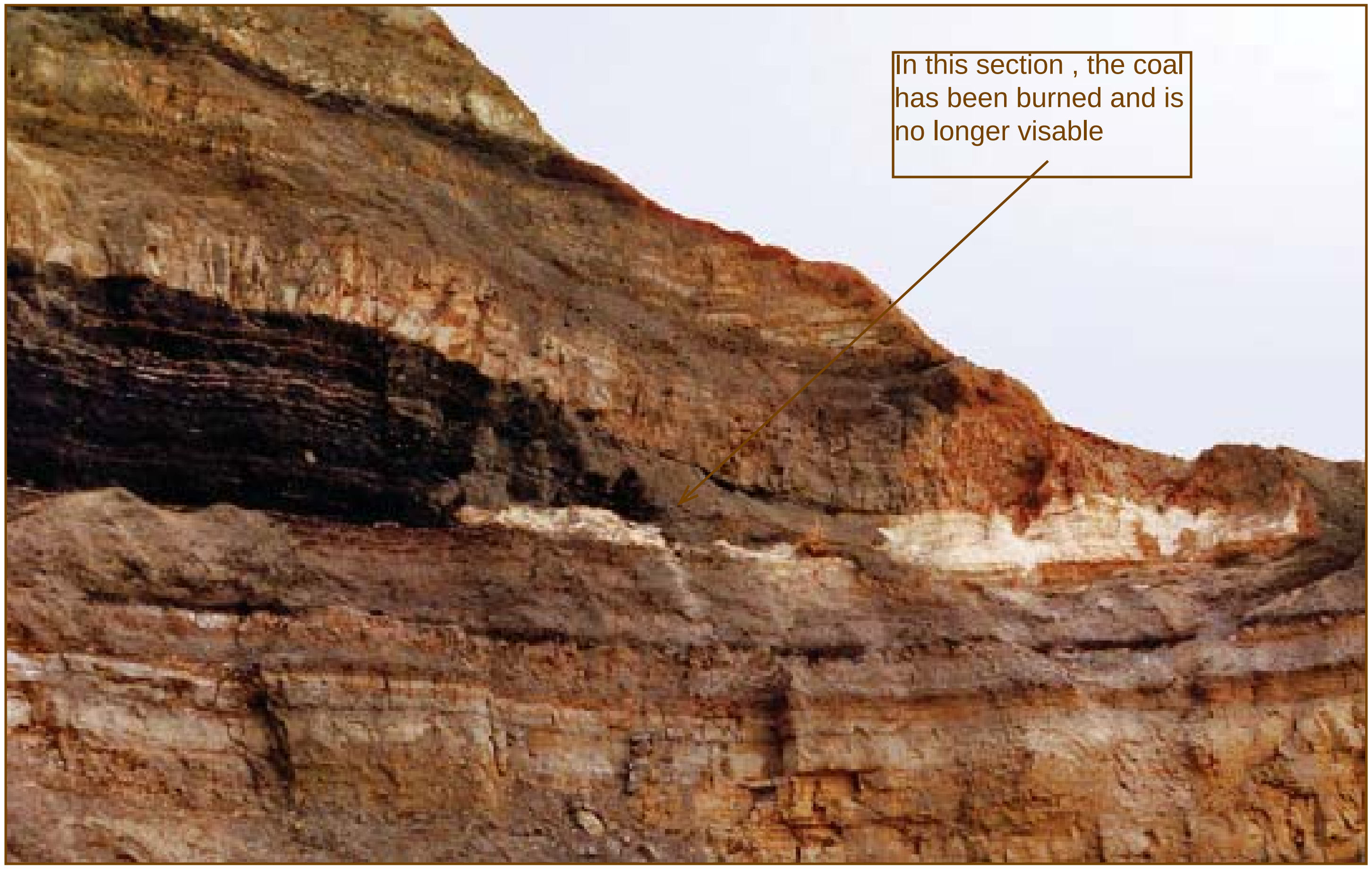


Photo courtesy of Ed Heffren, BLM State Office, Wyoming

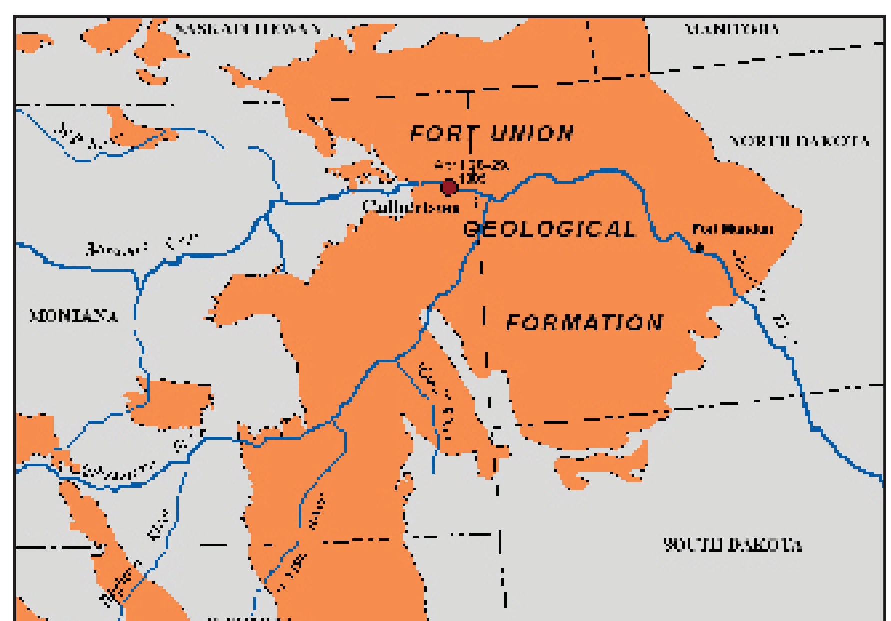
there is more appearance of coal today than we have yet seen, the stratas are 6 feet thick in some instances; the earth has been birnt in many places, and always ap-pears in stratas on the same level with the stratas of coal.

This photograph shows coal on the same level with clinker. The coal (to the left), which ends abruptly about photo center, is the unburned portion of the coalbed.

The Fort Union Formation

The coal-bearing Fort Union Formation underlies large areas of Montana, North Dakota and Wyoming.

About 65-55 million years ago, rivers flowing east from the rising mountains deposited alternating sequences of sand, silt and clay; these sediments ulti-mately consolidated into soft rock. The coalbeds originated in swamps along the rivers as decaying vegetation accumulated and slowly turned to peat.



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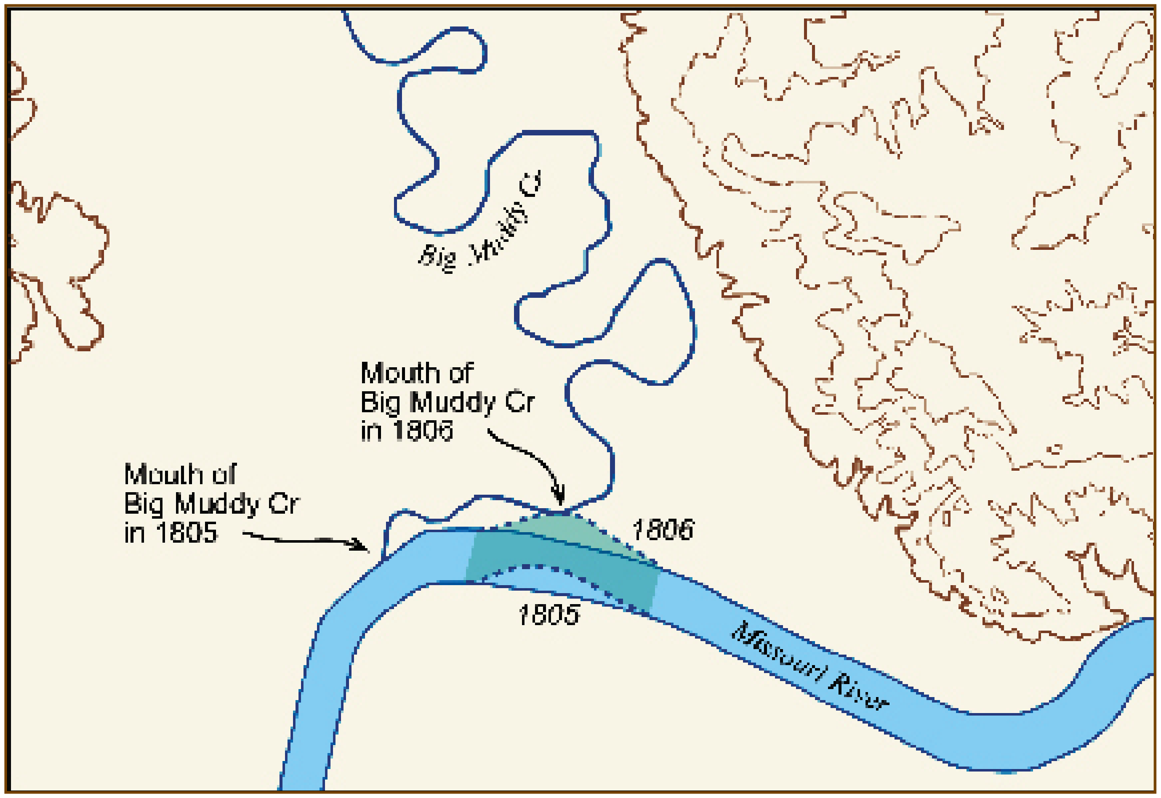
An ever-changing river . . .

Lewis, April 29, 1805:

we came too this evening in the mouth of a little river, which falls in on the Stard. side. **. . .** *This stream* **. . .** *Capt. C. named Marthas river . .*



On Lewis's return down the Missouri River, August 7, 1806 he wrote:

. . .we passed the entrance of Marthy's river which has changed its entrance since we passed it last year, falling in at present about a quarter of a mile lower down

Marthas River is Big Muddy Creek. The creek likely had found a new entrance to the Missouri during the spring of 1806. Meander development by both streams allowed high water to cut a passage between them a quarter of a mile downstream from the creek's former mouth.

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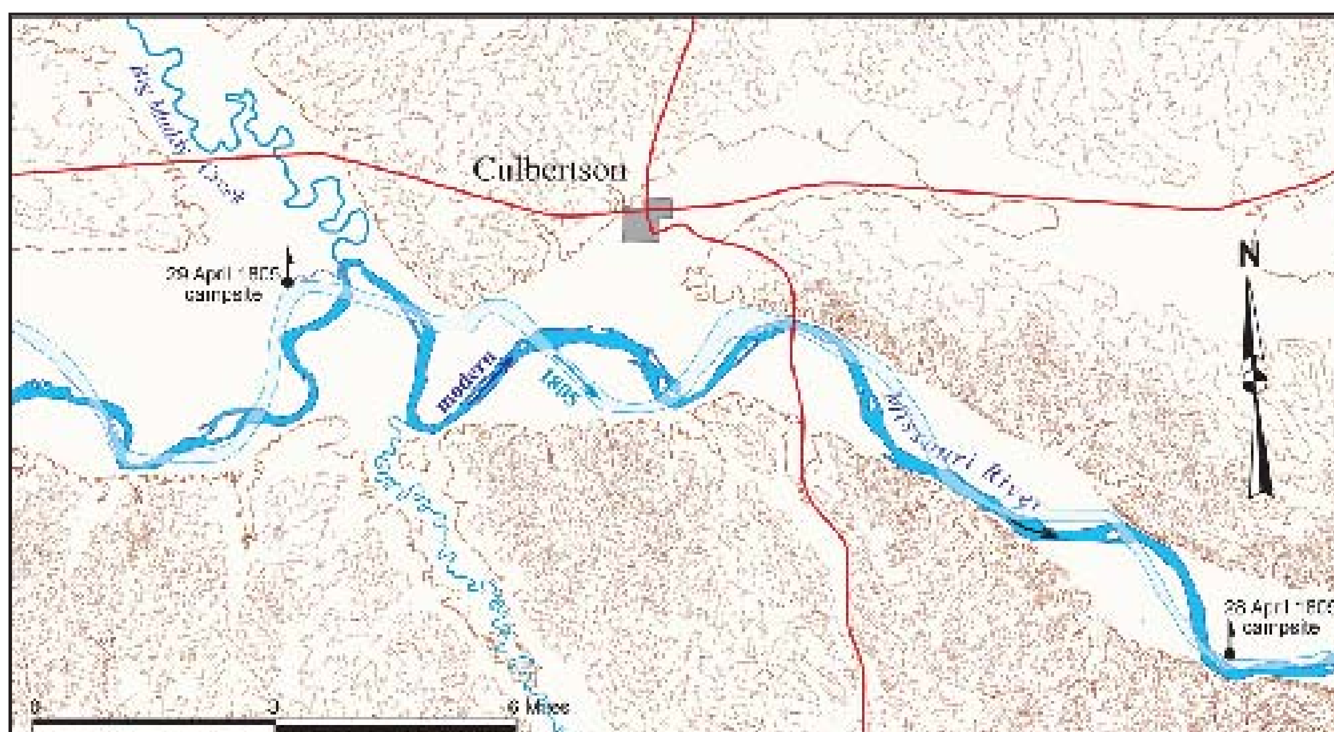
Rivers are dynamic systems — constantly shifting their course through erosion and deposition. The light blue pattern depicts the course of the Missouri River as Lewis and Clark mapped it. The dark blue pattern shows the Missouri's modern course.

The river's many course changes since 1805-06 have destroyed most of the expedition's campsites. .



The White Cliffs of the Missouri

Location Map

Lewis and Clark entered the Missouri Breaks on May 9, 1805 at present-day Fort Peck. Rugged topography and rock outcrops flank the Missouri throughout the Breaks, but the most spectacular scenery and geology are in the White Cliffs of the Missouri.

Lewis described this area on May 31:

> *The hills and river Clifts which we passed today exhibit a most romantic appearance. The bluffs of the river rise to the hight of from 2 to 300 feet and in most places nearly perpendicular; they are formed of remarkable white sandstone which is sufficiently soft to give*

Photo courtesy of Otto L. Schumacher

The “remarkable white sandstone” is the Virgelle Member of the Eagle Formation. Rivers deposited it as sand during the Cretaceous Period when a shallow sea covered much of interior North America. The sandstone contains many vertical cracks. Erosion and weathering widen the cracks, weakening the rock. Eventually slabs fall off, leaving near-vertical cliffs. The dark formation below the Virgelle is the Marias River Shale.

The water in the course of time . . . has trickled down the soft sand clifts and woarn it into a thousand grotesque figures

Photo courtesy of Brent Phelps

Photo by Ginette Abdo, MBMG

. . . with the help of less immagination we see the remains or ruins of eligant buildings; some collumns standing and almost entire with their pedestals and capitals . . .

Hard sandstone in the upper part of the Eagle Formation caps the Virgelle Member, protecting it from erosion. Without the cap rock the softer Virgelle sandstone erodes readily.

The hills and river Clifts which we passed today exhibit a most romantic appearance.

Photo courtesy of Wayne Mumford (www.waynemumford.com)

Photo courtesy of Otto L. Schumacher

Grand Natural Wall is one of many dikes that formed when magma forced its way into joints in the sedimentary rock. The dike rock here is more resistant than the surrounding sedimentary rock.

> *As we passed on it seemed as if those seens of visionary inchantment would never have an end; for here it is too that nature presents to the view of the traveler vast ranges of walls of tolerable workmanship*

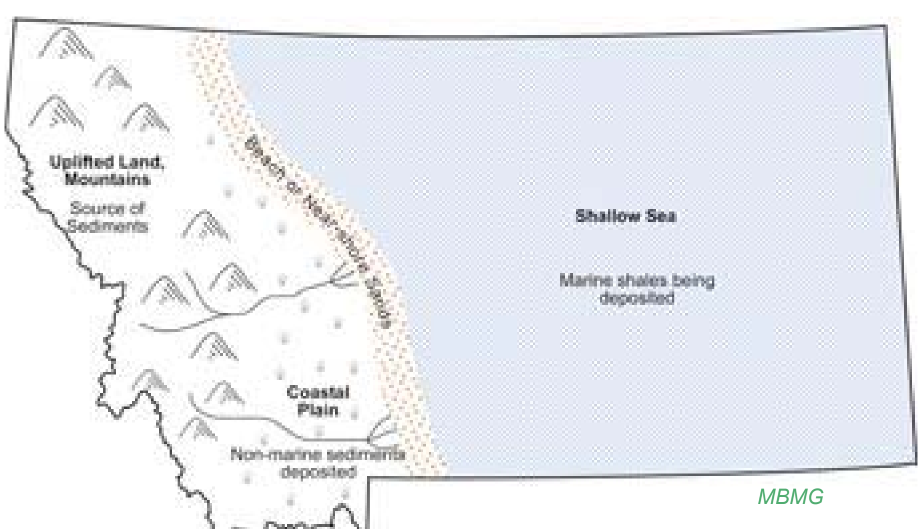
Lewis apparently did not realize that the dikes once were molten. He commonly identified most shiny crystals as talc or quartz, possibly considering them related minerals.

> *. . . these stones are almost invariably regular parallelepipeds, of unequal sizes in the walls, but equal in their horizontal ranges, at least as to debth.*

Shown is the parallelepiped shape Lewis noted; it results when cracks form as lava cools.

Photo by Ginette Abdo, MBMG

The Making of a Landscape



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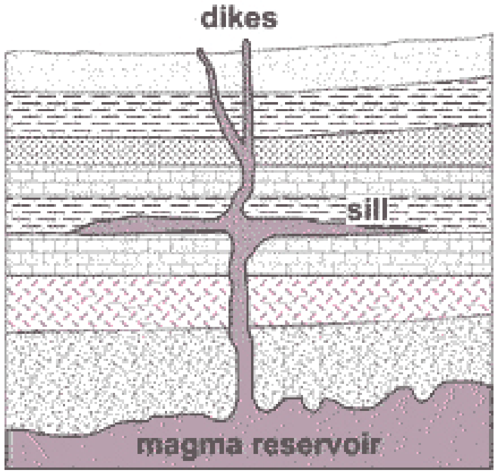
From sediment to rock

A shallow sea occupied the North American interior from 150 to 65 million years ago. When the Rocky Mountains began rising, rivers carried sediments eastward from them to this sea, depositing sand near its shore, silt and clay farther east in deeper water. Continued deposition buried the earlier sediments. Pressure and cementing solutions then changed sand, silt and clay into sandstone, siltstone and shale. Joints and cracks developed in these rocks.

Vulcanism

About 50 million years ago molten rock from deep within the earth rose up through joints in the overlying sedimentary rocks. Erosion has removed most of the volcanic outpouring, but the river cliffs here expose numerous near-vertical dikes.



Contact between a dike (brown) and sandstone (light-gray)

Photo by Ginette Abdo, MBMG

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Glacial ice forces the Missouri to carve a new course through northern Montana

Rivers re-routed

Glacial ice entered northern Montana several times during the ice ages (1.6 million to 10,000 years ago). About 160,000 to 130,000 years ago, ice blocked the Missouri's course northeast of Great Falls. Lakes formed in the rivers south of the ice. Lake levels rose until their waters cut channels into adjacent drainages. Ultimately, the entire flow of the Missouri was rushing eastward in a new valley, carving and deepening it as it went. Smaller streams later occupied much of the Missouri's former valley.

Photo courtesy of Wayne Mumford (www.waynemumford.com)

Erosion of the Missouri

The Missouri River in the upper Breaks area is still carving its new course as evidenced by the valley walls that are steeper than those along its preglacial course.

A drop of rain, a downpour, wind, frost, running water **. . .** all erode the soft Virgelle sandstone, carving it into the "thousand grotesque figures"

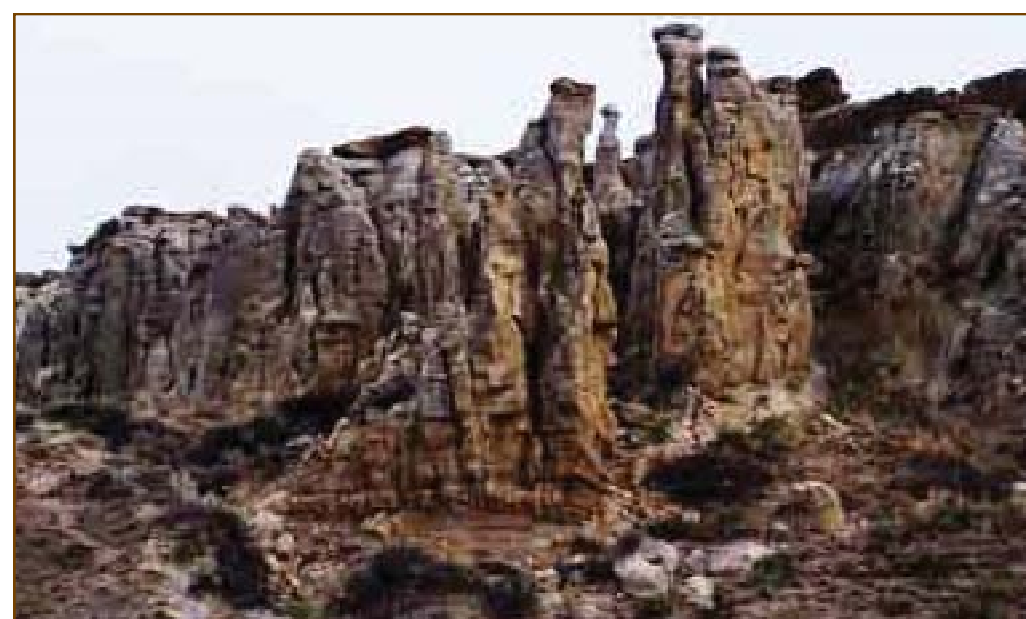


Photo by Ginette Abdo, MBMG

Great Falls of the Missouri

Meriwether Lewis left Clark at the Marias River on June 11, 1805 and set out to find the falls of the Missouri.

On June 13, while walking a mile north of that river:

. . . my ears were saluted with the agreeable sound of a fall of water and advancing a little further I saw the spray arrise above the plain like a collumn of smoke which would frequently dispear again in an instant . . . I did not however loose my direction to this point which soon began to make a roaring too tremendious to be mistaken for any cause short of the great falls of the Missouri.

1.) About noon he reached Big Falls . . .

I hurryed down the hill which was about 200 feet high and difficult of access, to gaze on this sublimely grand specticle. I took my position on the top of some rocks about 20 feet high opposite the center of the falls. . . . the remaining part of about 200 yards on my right formes the grandest sight I ever beheld . . .

2.) Lewis headed upstream on the morning of June 14 to see how far the falls continu About 5 miles from the Big Falls he:

. . . arrived at a fall of about 19 feet; the river is here about 400 yds. wide. this pitch which I called the crooked falls occupys about three fourths of the width of the river . . .

Big Falls

Photo courtesy Montana Historical Society, Haynes Foundation Collection

Crooked Falls

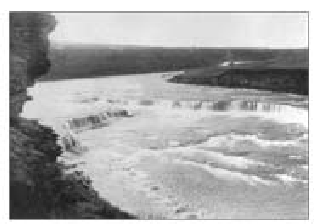


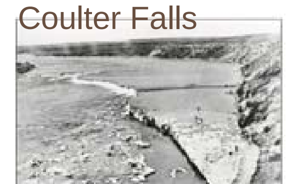
Photo courtesy Montana Historical Society

Rainbow Falls

Photo courtesy Montana Historical Society

Black Eagle Falls

Coulter Falls



Photos courtesy Cascade County Historical Society

3.) Carefully noting the particulars of Crooked Falls, Lewis then **. .**

. . . hearing a tremendious roaring above me I continued. . . a few hundred yards further and was again presented by one of the most beatifull objects in nature, a cascade of about fifty feet perpendicular streching at rightangles across the river from side to side to the distance of at least a quarter of a mile. here the river pitches over a shelving rock, with an edge as regular and streight as if formed by art, without a nich or brake in it; the water decends in one even and uninterrupted sheet . . .

4.) It was near noon on June 14, when Lewis continued upstream from Rainbow Falls:

. . . I discovered another fall above at the distance of half a mile . . . I found this to be a cascade of about 14 feet possessing a perpendicular pitch of about 6 feet. . . . in any other neighbourhood but this, such a cascade would probably be extoled for it's beaty and magnificence, but here I passed it by with but little attention . . .

5.) After passing Colter Falls Lewis:

. . . arrived at another cataract of 26 feet. this is not immediately perpendicular, a rock about ⅓ of it's decent seems to protrude to a small distance and receives the water in it's passage downwards and gives a curve to the water tho' it falls mostly with a regular and smoth sheet. the river is near six hundred yards wide at this place . . . below this fall at a little distance a beatifull Island well timbered is situated about the middle of the river. in this Island on a Cottonwood tree an Eagle has placed her nest; a more inaccessable spot I beleive she could not have found . . .

Creating the Falls

Start with the rocks

Rivers flowing from the west deposited alternating layers of sand, silt and mud on the coastal plain and shore of a sea that occupied this area during the Early Cretaceous Period. These sediments became the sandstone, siltstone and mudstone of the middle part of the Kootenai Formation.

The Sunburst Sandstone at Big Falls

The Sunburst Sandstone (deposited 120 million years ago) is a resistant sandstone at the base of the middle Kootenai Formation. Deposits typical of tidal channels and estuaries have been identified in these rocks and can be seen north of Ryan Island Park. The height of Big Falls (about 90 feet) is partly due to the thickness of the Sunburst Sandstone there.

Beds overlying the Sunburst — the upper falls

The middle Kootenai Formation rocks that overlie the Sunburst Sandstone are alternating layers of thin sandstone and less resistant siltstone and mudstone. The sediments were deposited in stream beds and interstream areas inland from the shore on a coastal plain or delta plain; they show no evidence of marine conditions.

Middle Kootenai Formation near Ryan Island Park and Big Falls

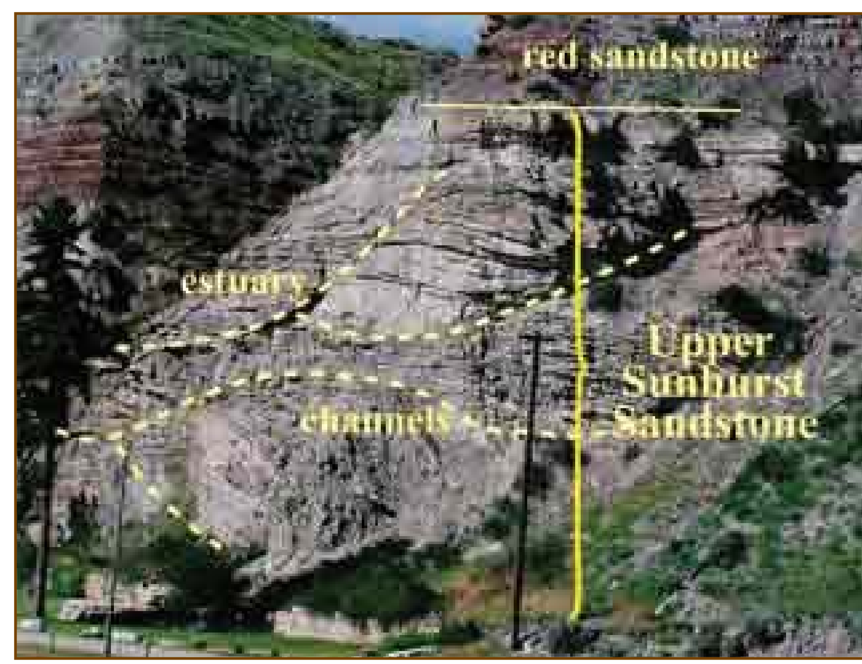


Photo courtesy of Robert K. Schwartz

Crooked, Rainbow, Coulter, and Black Eagle falls cascade over these rocks

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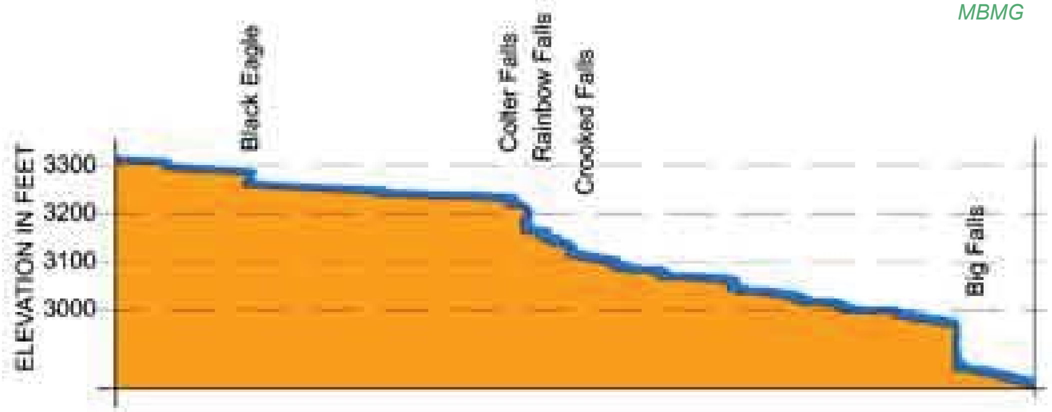
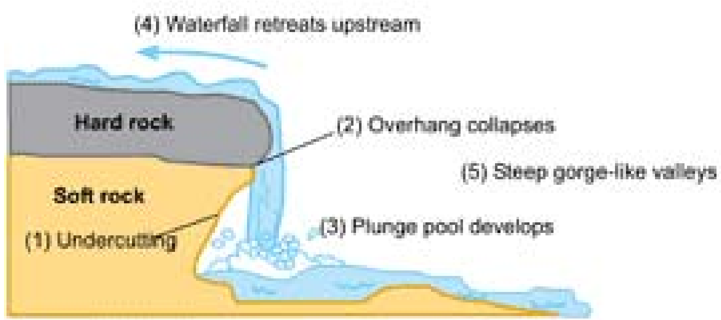


Bring on the Glaciers

About 15,000 years ago glacial ice advanced just south of Great Falls, burying the Missouri's valley. When the ice retreated, the Missouri River cut a new channel between Sand Coulee Creek and Box Elder Creek (see map). Torrents of water began draining through this new channel.

Post-Glacial Erosion

The Missouri cut its new channel through resistant sandstone interbedded with less resistant siltstone and mudstone. Waterfallsformed as the river flowed over the jointed and fractured rock. Eventually falling water undercuts the more resistant sandstone layers and, as the undercut enlarges, the sandstone collapses along joint surfaces. This process continues and the waterfall moves upstream.



FORMATION OF A WATERFALL

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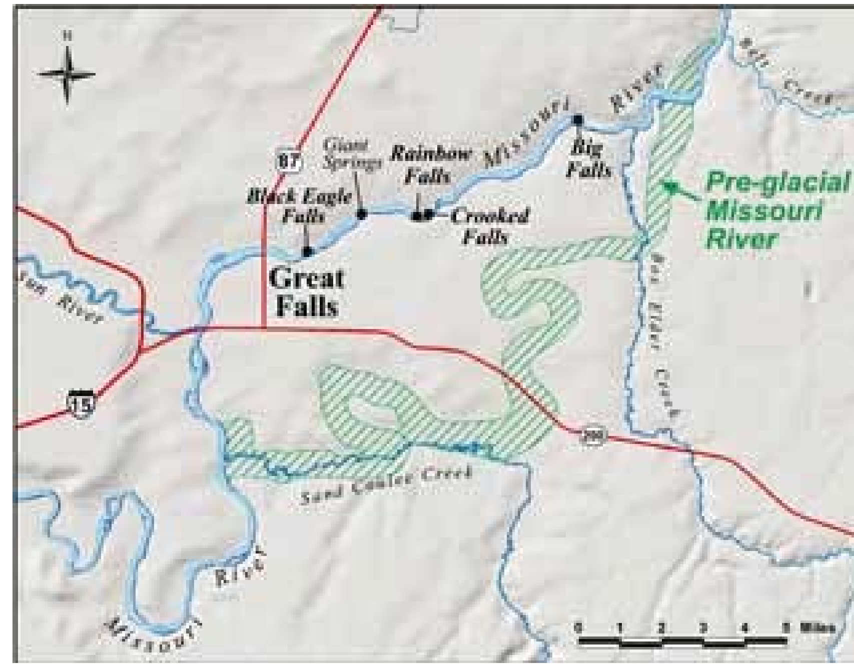
Lewis and Clark might be amazed at how little water sometimes flows over the falls today — five dams control flow along this section of the Missouri.



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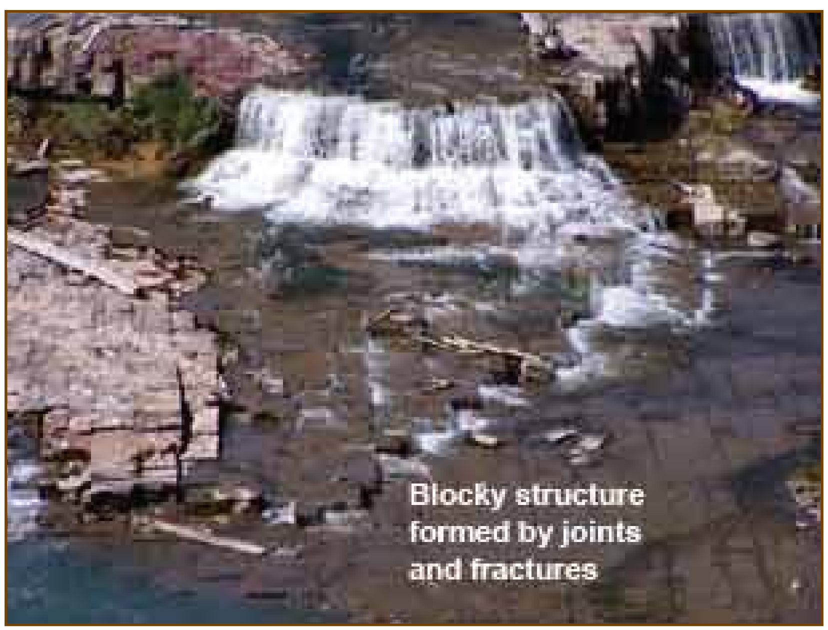
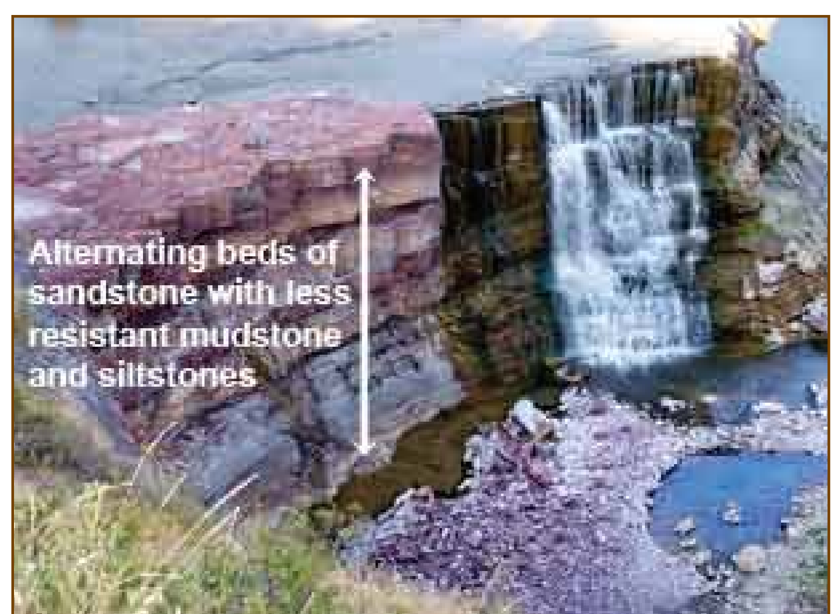


Layers of maroon-colored mudstone and siltsone in the Kootenai Formation form the Black Eagle Falls. Flowing water cuts into the less resistant beds, undermining the more resistant ones.

Photos by Ginette Abdo, MBMG

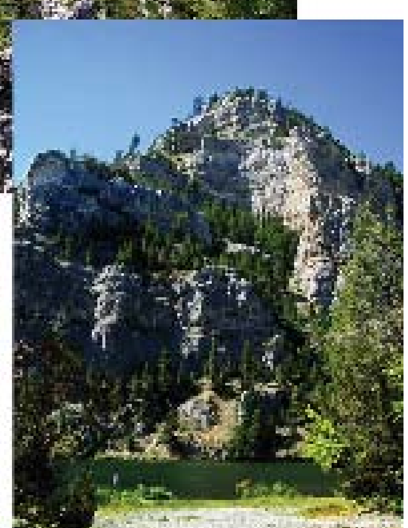


The much-reduced flow of water over Black Eagle Falls provides a good view of the layering in the Kootenai Formation and also the blocky structure produced by jointing and fracturing. Water flowing along the joints and fractures contributes to the development of the falls

Gates of the Mountains

The Lewis and Clark Expedition spent a month near the falls of the Missouri River then continued upriver on July 15, 1805. Two days later they reached the mountains and, on July 19, Lewis recorded:

. . . this evening we entered much the most remarkable clifts that we have yet seen. these clifts rise from the waters edge on either side perpendicularly to the hight of 1200 feet. every object here wears a dark and gloomy aspect. the tow[er]ing and projecting rocks in many places seem ready to tumble on us. the river appears to have forced it's way through this immence body of solid rock for the distance of 5¾ miles and where it makes it's exit below has thrown on either side vast collumns of rock mountains high. the river appears to have woarn a passage just the width of it's channel or 150 yds. it is deep from side to side nor is ther in the 1st 3 miles of this distance a spot except one of a few yards in extent on which a man could rest the soal of his foot.



Photos by Ginette Abdo, MBMG

The cliffs that form the Gates of the Mountains, as Lewis noted, are about 5¾ miles in length, but rise about 1,000 feet above the water. For Lewis "evening" means "late afternoon," at which time the entire west side of the gates and the eastern base would have been in shadow, possibly eliciting his description: every object here wears a dark and gloomy aspect.

The tow[er]ing and projecting rocks in many places seem ready to tumble on us.

Gates of the Mountains area, looking north. The Missouri River began to shape this canyon 2 to 3 million years ago when it meandered over softer rocks that covered the rocks now exposed in the canyon. By the time the river cut into the harder rocks it was "trapped" in this course and carved the deep gorge we see today.

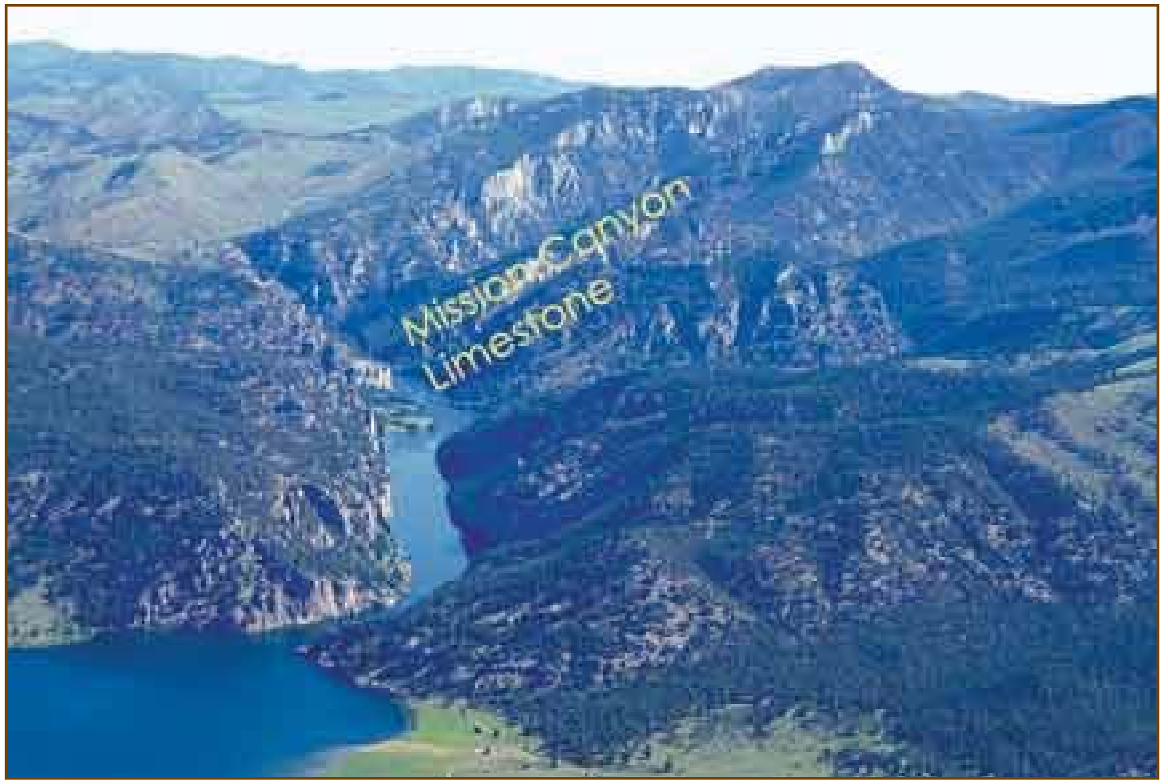


Photo courtesy of Mitchell W. Reynolds, U.S. Geological Survey

Photo courtesy of Michael Barth

. . . from the singular appearance of this place I called it "the gates of the rocky mountains."

Seen from the downstream end of the Gates, great rock walls appear to block the river. As one draws nearer, however, the rock formations open to a deep, narrow gorge.

. . . several fine springs burst out on the waters edge from the interstices of the rocks.

Holter Dam, constructed in 1918 about 10 miles downstream from the Gates of the Mountains, has raised water levels in the Gates by about 30 feet. The springs that Lewis noted are now underwater.

The interstices (openings) in the rock developed when ground water, moving through fractures in the rock and reacting with the limestone, formed carbonic acid — which dissolves the limestone.

Photo courtesy of Michael Barth

. . this rock is a black grannite below and appears to be of a much lighter colour above and from the fragments I take it to be flint of a yelloish brown and light creemcoloured yellow.

There is no granite in or adjacent to the Gates of the Mountains. The gorge is carved into rocks of Mississippian age, predominantly the Mission Canyon Limestone, which was deposited 325 million years ago when a shallow sea occupied much of Montana. This limestone was folded when the Rockies were being formed 70 to 65 million years ago, and great slabs of rock were thrust up and over other rocks.

The freshly broken, unweathered limestone is dark gray. Seen in the shadow of the cliffs, it may have prompted Lewis's description of the black color. The exposed, weathered limestone surfaces are lighter in color — cream to yellowish orange.

Photos by Ginette Abdo, MBMG

. . . flint of yellowish brown and light creemcoloured yellow.

By modern definition there is no flint in the Gates of the Mountains area. The upper section of the Mission Canyon Limestone, however, contains chert, and the term flint now refers to a variety of chert that is dark brown or black.

Three Forks of the Missouri

Upstream from the Gates of the Mountains the river cliffs became lower, and a few miles south of present-day Canyon Ferry, the mountains stood miles from the river. In this wide valley on July 22, 1805, Sacagawea recognized a place where her Shoshone relatives dug a white soil to make ceremonial paint. She also assured Lewis that the Three Forks of the Missouri were “at no great distance.”

Clark set out the next morning with four men to look for the Shoshone again, hoping to obtain horses to cross the mountains to Pacific waters. He arrived at the Three Forks early on July 25, then explored the Jefferson and Madison rivers before rejoining the main party on the 27th, ill and with a high fever.

Lewis and the main party made camp on July 26 about seven miles down river from the Three Forks. The next morning, July 27, while continuing upstream, Lewis noted:

> *. . . the river was again closely hemned in by high Clifts of a solid limestone rock which appears to have tumbled or sunk in the same manner as those discribed yesterday*

About a mile west (upstream) from Lewis’s July 26 camp, limestones of the Madison Group form the outcrops along both sides of the Missouri River. These limestones were deposited in a shallow sea that occupied the Rocky Mountain region during the Mississippian Period (about 325 million years ago). During the Late Cretaceous Period (about 100 to 65 million years ago), these marine rocks were folded, faulted, and uplifted by mountain-building processes.

Lewis’s view looking upstream (south) on the Missouri River, July 27th, four miles from the confluence of the Three Forks.

The rocks are tilted (dip) 40-50° to the west. It is not surprising that Lewis concluded that these rocks had been undermined by the river.

Photos by Ginette Abdo, MBMG

Geologic cross section showing the dipping beds that may have appeared to Lewis *“to have tumbled or sunk.”*

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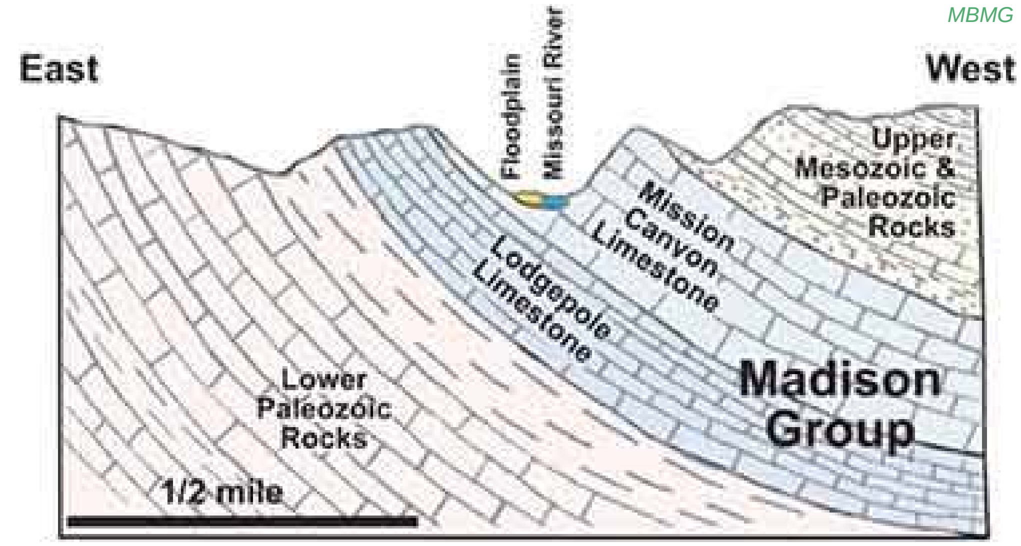


Note the “ light led colour” of the weathered limestone

Note the “ light led colour” of the weathered limestone

Photos by Ginette Abdo, MBMG.

. . . the limestone appears to be of an excellent quality of deep blue colour when fractured and of light led colour where exposed to the weather. it appears to be of a very fine gr[a]in and the fracture like that of marble.

The limestone Lewis described is part of the Mission Canyon Formation, upper member of the Madison Group limestones. Notice the difference in color that Lewis observed between the weathered and unweathered (fresh) pieces of the limestone.

. . . we arrived at 9 A.M. at the junction of the S.E. fork of the Missouri and the country opens suddonly to extensive and beatifull plains and meadows which appear to be surrounded in every direction with distant and lofty mountains; supposing this to be the three forks of the Missouri I halted the party on the Lard. shore for breakfast and walked up the S. E. fork about ½ a mile and ascended the point of a high limestone clift from whence I commanded a most perfect view of the neighbouring country.

From the top of the “high limestone cliff”, Lewis had a magnificent view of the Gallatin, Madison, and Jefferson rivers, the extensive plains surrounding them, and the snowcapped peaks of the Bridger, Gallatin, Madison, and Tobacco Root ranges. Faulting in western Montana during the early and middle Tertiary Period (55–20 million years ago) raised some blocks of the earth’s crust and down-dropped others. Sediments from the raised blocks (now the mountain ranges) washed into the down-dropped blocks (intermontane valleys), partly filling them to form the “extensive plains” that Lewis described.

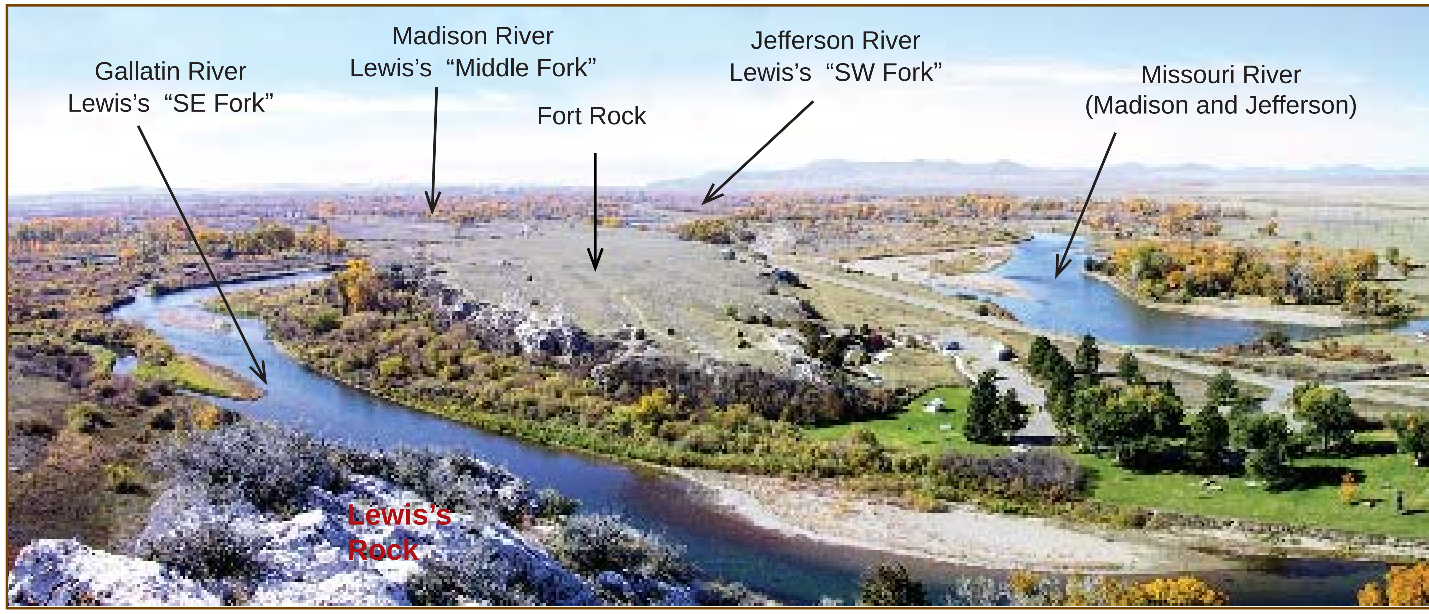
From this vantage point, atop Lewis’s Rock, Lewis observed:

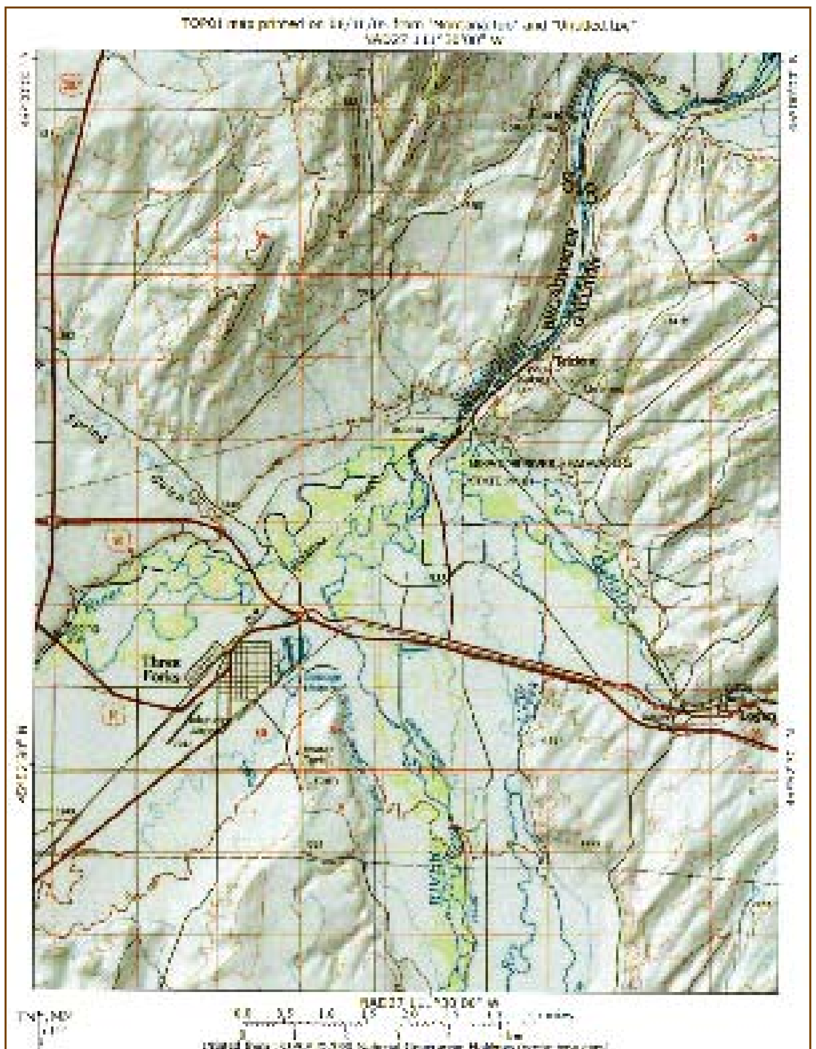
between the middle and S. E. forks near their junction with the S.W. fork there is a handsom site for a fortification it consists of a limestone rock of an oblong form; it’s sides perpendicular and about 25 ft high except at the extremity towards the middle fork where it ascends gradually and like the top is covered with a fine terf or greenswoard. the top is level and contains about 2 Acres. the rock [r]ises from the level plain as if it had been designed for some such purpose:

Lewis’s view of the surrounding area was from the top of this outcrop–now called Lewis’s Rock

The limestone rock Lewis described, called Fort Rock, is a broad outcrop of Mission Canyon limestone. This generally flat-topped feature is 2800 feet long by 800 feet wide and rises a little more than 40 feet above the floodplain. The long axis of the outcrop trends southwest-northeast, approximately paralleling a thrust fault (from the mountain-building episode). The Gallatin River forms the eastern boundary of the feature, separating it from Lewis’s Rock.

Looking southwest from Lewis's Rock. The three rivers have shifted course many times since 1805. Today, where the Madison and Jefferson forks meet, the Missouri River begins, joined a short distance downstream (to the right) by the Gallatin River.





Lewis set up camp on the Jefferson just upstream from its junction with the Madison River. Convinced that the Three Forks was an essential point in the geography of Western part of North America, he wanted to take celestial observations to obtain its latitude and longitude.The party camped here for three nights before ascending the Jefferson River.

Three Forks Area

Beaverhead Rock

Meriwether Lewis completed his celestial observations at the Three Forks of the Missouri about 8:30 pm on July 29, 1805. The next morning, the Corps of Discovery headed up the Jefferson River. On August 1, Lewis and three men began scouting ahead on foot; they reached the three forks of the Jefferson River on August 3. Clark, with the canoes, joined them on August 6.

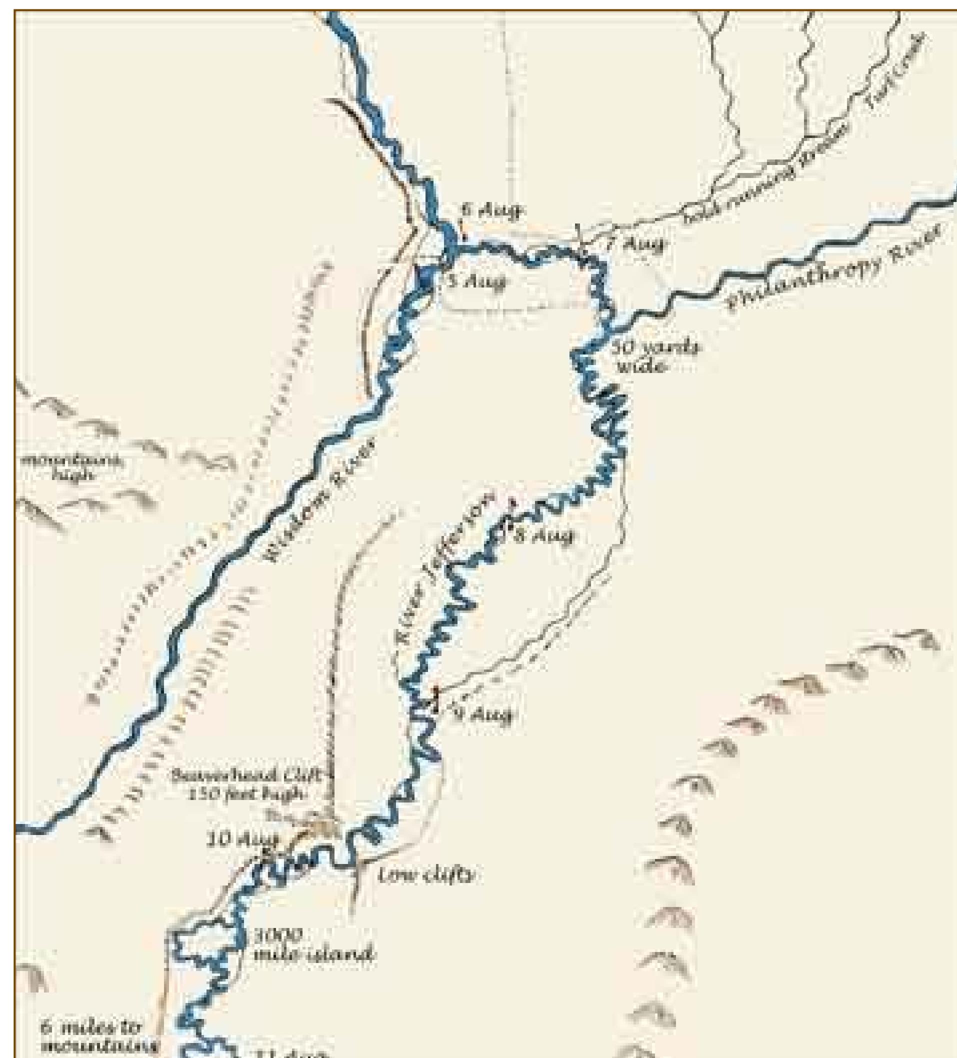
Lewis named the Jefferson River's southeast fork Philanthrophy River (now Ruby River) and the southwest fork Wisdom River(now Big Hole River) in "commemoration of two of those cardinal virtues, which have eminently marked that deservedly selibrated character [Thomas Jefferson] through life." The captains decided to follow the Jefferson River (now Beaverhead sketch by William ClarkRiver), believing that it would provide the best route over the mountains to the Columbia River

Lewis recorded that on August 8, Sacagawea . . .

. . . recognized the point of a high plain to our right which she informed us was not very distant from the summer retreat of her nation on a river beyond the mountains which runs to the west. this hill she says her nation calls the beaver's head from a conceived remblance of it's figure to the head of that animal. . .

On August 10, while Lewis again scouted ahead, Clark passed Beaverhead Rock with the canoes:

. . . we proceeded on passed a remarkable Clift point on the Stard. Side about 150 feet high, this Clift the Indians Call the Beavers head, opposite at 300 yards is a low clift of 50 feet which is a Spur from the Mountain on the Lard. about 4 miles . . .



Clark's map of the Beaverhead Rock area

modified by Bob Bergantino, MBMG

North South

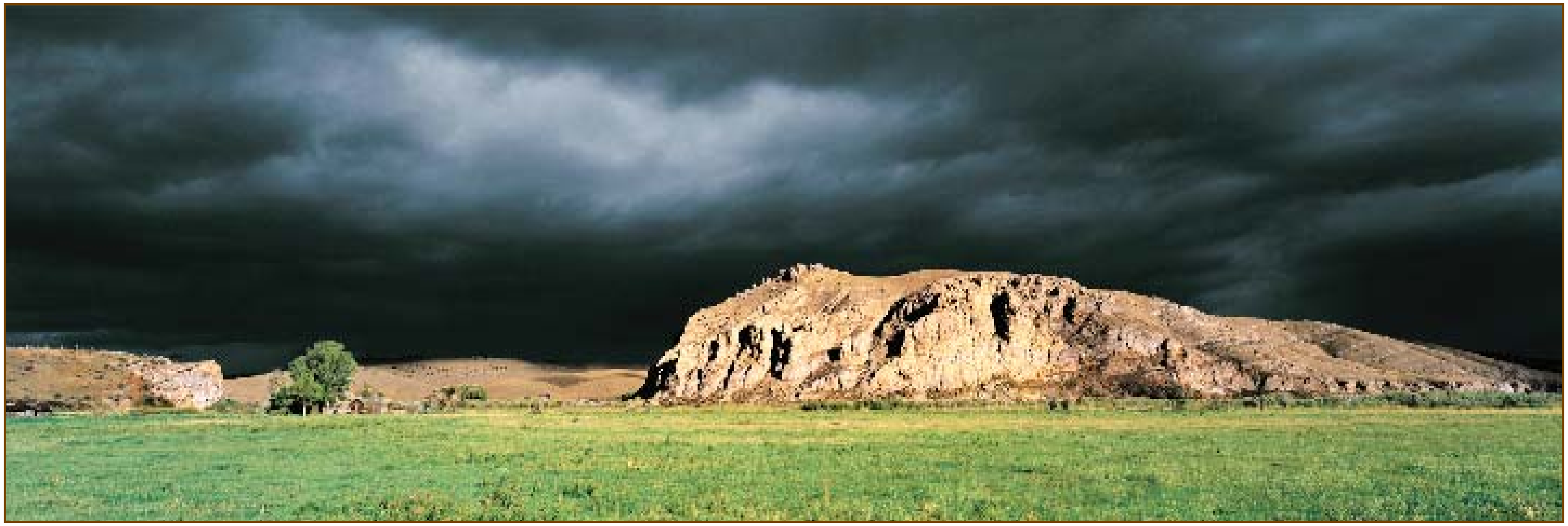


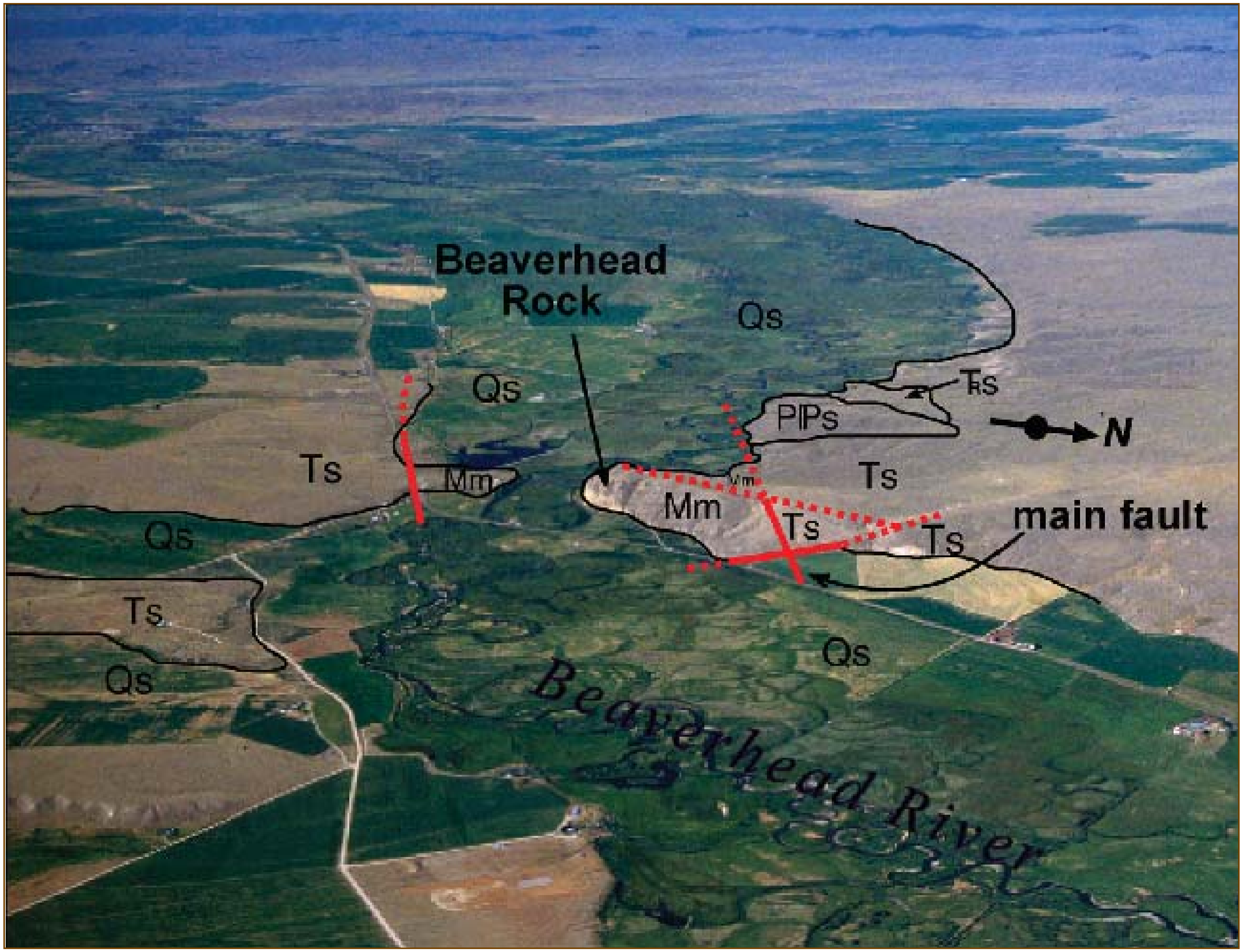
Photo courtesy of Brent Phelps

With the help of a little imagination a beaver's head can be seen in the cliff on the right. The rock cliff on the left side of the river is not structurally or topographically related to the Ruby Mountains to the east; that is, it is not a spur from them as Clark thought. The summit of Beaverhead Rock actually stands about 380 feet above the river, that is, 230 feet higher than Clark's estimate.

Ages before Lewis and Clark arrived, Beaverhead Rock was a well known landmark to Native Americans of this area. The "Rock" is composed of gently west-dipping Mississippian-age Mission Canyon Limestone — the same formation exposed in the Gates of the Mountains and near the Three Forks of the Missouri. Deposited over 325 million years ago in a shallow sea that covered much of interior North America, the Mission Canyon Limestone (part of the Madison Group of limestones) crops out in many mountain ranges in Montana.

East West

Photo courtesy of Ginette Abdo, MBMG



Air photo courtesy of Hugh Dresser

Faulting in this area several million years ago raised a block of the earth's crust. As the Beaverhead River eroded the softer, younger deposits that capped and surrounded the fault block, the more resistant Mission Canyon Limestone remained as a prominent cliff.

* ***Qs*** *Sediments of modern streams, flood plain and lower slopes*
* ***Ts*** *Sediment and sedimentary rock of Tertiary Period (2.5-65 million years ago)*
* ***TRs*** *Sedimentary rock of Triassic Period (206-248 million years ago)*
* ***PIPs*** *Sedimentary rocks of Permian and Pennsylvanian Periods (248-325 million years ago)*
* ***Mm*** *Sedimentary rocks (Mission Canyon Limestone) of Mississippian Period (325-354 million years ago)*
* _____ *Contacts*
* ----- - - *Faults, dashed where covered*

Pompey's Pillar

Location Map

Lewis and Clark split the expedition into two exploring parties at Travelers Rest near present-day Lolo, Montana on July 3, 1805. They planned to rejoin at the mouth of the Yellowstone River. Clark's party included Sacagawea and little Jean Baptiste. One of Clark's objectives was to explore the Yellowstone River. About 25 miles southwest of present-day Billings, Montana Clark's party built dugout canoes; they launched them on July 24. By mid-afternoon on July 25, the canoes had traveled more than 50 miles down river to the northeast:

. . . at 4 P M arrived at a remarkable rock Situated in an extensive bottom on the Stard. Side of the river & 250 paces from it. this rock . . . I shall Call Pompy's Tower is 200 feet high and 400 paces in secumphrance and only axcessable on one Side which is from the N.E. the other parts of it being a perpendicular Clift of lightish Coloured gritty rock . . .

Photo by Ginette Abdo, MBMG

Clark's likely named this feature for Jean Baptiste Charbonneau, nicknamed Pomp. In the first edition of the History of the Lewis and Clark Expedition (1814), however, the name became Pompeys Pillar. The pillar was proclaimed a National Monument in 2001.

The height of the pillar is about 130 feet, substantially lower than Clark's estimated 200 feet. Its base is oval-shaped, about 370 feet by 480 feet, and is nearly 400 yards around.

Photo by Ginette Abdo, MBMG

Lewis and Clark left few physical marks on the land as they passed. Clark's engraved signature on Pompeys Pillar is one of them. Rain, wind and frost wear away the soft sandstone that forms this Pillar, and inscriptions soon fade unless deeply incised.

Clark's original signature still could be read in 1876, but has been re-engraved several times. It now is enclosed and protected.

The nativs have ingraved on the face of this rock the figures of animals &c. near which I marked my name and the day of the month & year.

W.R. Plywell, with the Stanley Expedition (1873), photographed Pompeys Pillar from the cliffs north of the river. Today trees obscure the Pillar from this site.

Photo (no. 106-YX-36) courtesy of the National Archives

How did the Pillar Form?

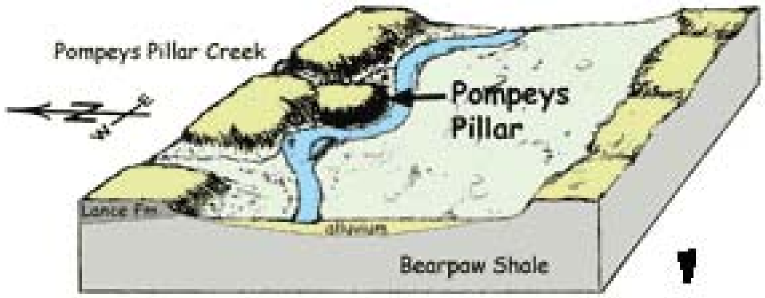
Photo by Ginette Abdo, MBMG

About 65 million years ago, during the Late Cretaceous Period . . .

. . . rivers flowing eastward from the rising Rocky Mountains carried sand, silt, and clay to a shallow sea just east of present-day Montana. The sand and silt those rivers deposited here became, with time and compaction, *the lightish Coloured gritty rock* that Clark described. Geologists call this the Lance Formation.

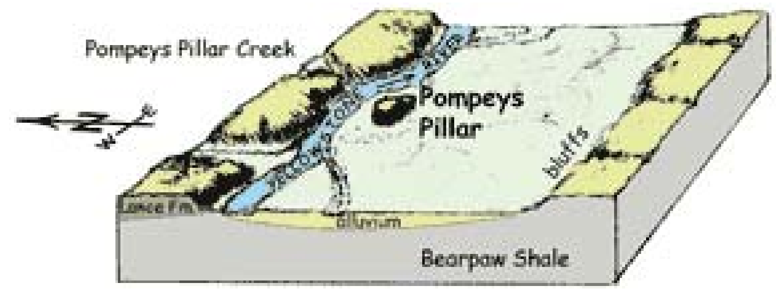
Several million years ago . . .

. . . the Yellowstone River meandered over its flood plain much as it does now, gradually cutting its valley deeper. What is now Pompeys Pillar was once part of the cliffs north of the river.



A meander began to eat into the cliff north of the present Pillar, forming a low neck. Pompeys Pillar Creek also cut into the weak rock there.

When, likely during a flood, the river breached the low neck, separating the Pillar from the cliffs north of the river, isolating it on the south side.



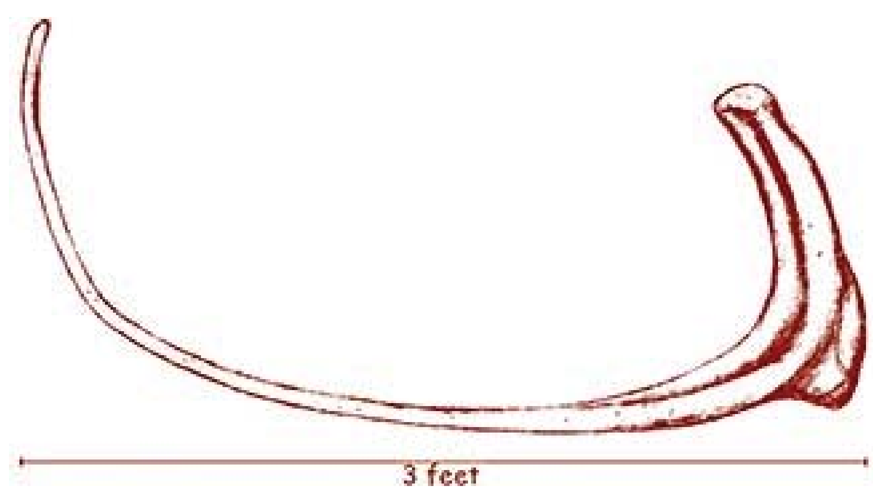
the rib of a fish.

About 6 miles down river from Pompeys Pillar forty bighorn sheep crowded the cliff north of the river. The canoes landed and Clark climbed the cliff. Near the top Clark found a bone protruding from the soft rock

Rocky cliff that Clark may have climbed..

Photo by Ginette Abdo, MBMG

. . . I employed my Self in getting pieces of the rib of a fish which was Semented within the face of the rock. this rib is [about 3] inchs in diame Secumpherance about the middle… it is 3 feet in length tho a part of the end appears to have been broken off. I have Several pieces of this rib. the bone is neither decayed nor petrified, but very rotten.



Reconstruction of the “rib of a fish” from Clark’s description and a small sketch he made on a map of this area
—Bob Bergantino, MBMG

The bone is from a terrestrial dinosaur — perhaps a Triceratops or Tyrannosaurus. The rock that held this bone is part of the Lance Formation (Cretaceous). Dinosaurs were not recognized as a distinct group of animals until 1840.

Powder River and the Terry Badlands

As Clark descended the Yellowstone River he dutifully noted the many natural features he saw. A modern traveler here still can see and appreciate what he described:

Friday July 30th, 1806 At the mouth of the Powder River, Clark noted:

> *. . . the water . . . is 100 yds wide, the bead to this river nearly ¼ of a mile this river is Shallow and the water very muddy and of the Colour of the banks a darkish brown. I observe great quantities of red Stone thrown out of this river that [and] from the appearance of the hills at a distance on its lower Side induced me to call this red Stone river.*

The Powder River flows into the Yellowstone River about seven miles southwest of Terry, Montana.

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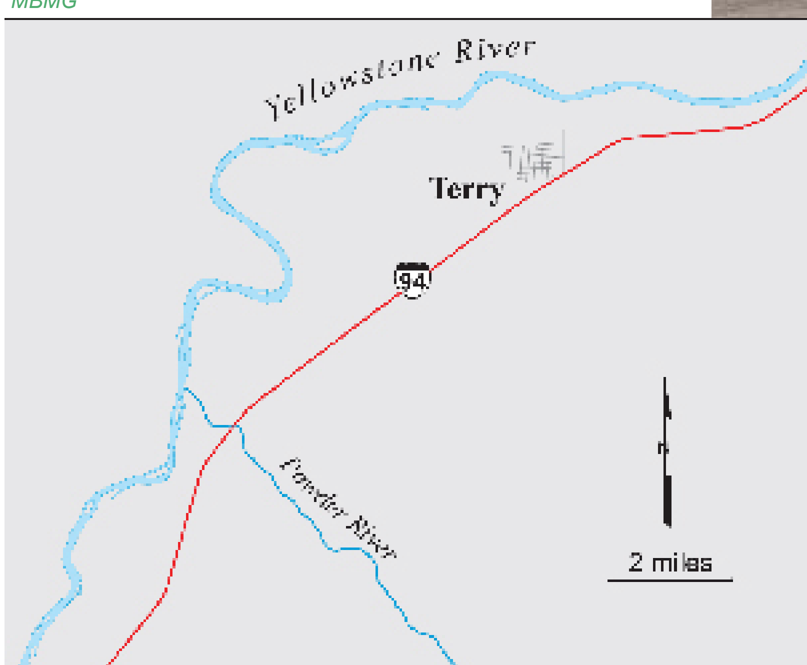


Photo by Ginette Abdo, MBMG

Confluence of the Yellowstone and Powder River — which derives its name from the fine, gray sediment along its banks, said to look like gun powder.

Photos by Ginette Abdo, MBMG

The red rocks in and near this stream induced Clark to call it red Stone river.

Photo by Clay Schwartz, MBMG

The red-colored stones are chunks of clinker from the Fort Union Formation that washed or fell into the river, which tumbled and smoothed them. Clinker forms when lightning, grass fires, or spontaneous combustion ignites coal beds, and the adjacent rock — if siltstone or shale — is baked and fused, forming orange, red and yellow "burned rock."

Photos by Ginette Abdo, MBMG

These banks a darkish brown are near the mouth of the Powder River and are composed of layers of silty clay deposited by the river. Erosion of these sediments produces the mud in the river and its muddy look.

The next day, July 31, Clark continued downstream about 7 miles past Powder River to present-day Terry, Montana

This high Country is washed into Curious formed mounds & hills and is cut much with reveens.

. . . here the river approaches the high mountainous country on the N W. Side. those hills appear to be composed of various Coloured earth and Coal without much rock. I observe Several Conical pounds which appear to have been burnt. this high Country is washed into Curious formed mounds & hills and is cut much with reveens.

The high Country is entirely bar of timber. great quantities of Coal or carbonated wood is to be seen in every Bluff and in the high hills at a .distance on each Side.

Photo courtesy of Wayne Mumford (www.waynemumford.com)

The rugged hills on the N.W. Side of the Yellowstone are the Terry badlands carved out of the Fort Union Formation. The darker, patterned, flat area south of the river is flood plain alluvium, formed by modern erosion and flood deposits.

. . . I observe several conical pounds [mounds] which appear to have been burnt.

These mounds are capped with erosion-resistant clinker — shale and siltstone that were baked when the underlying coal beds burned.

. . . great quantities of Coal or carbonated wood is to be seen in every Bluff and in the high hills at a distance on each Side.

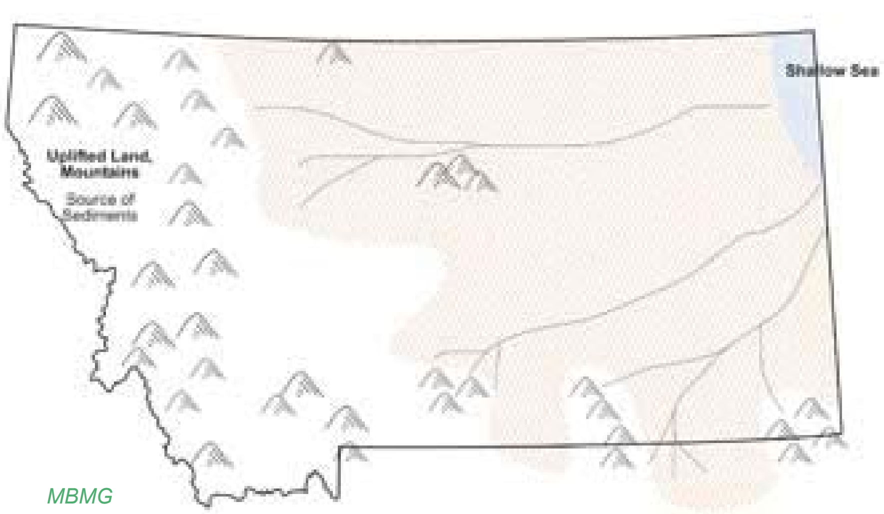
Photo by Ginette Abdo, MBMG

The dark layers are coal formed 65-55 million years ago from the decay of vegetation in swampy area

Photo by Ginette Abdo, MBMG

Lewis and Clark sometimes called the coal of eastern Montana and western North Dakota "carbonated wood" because it contained the remains of the woody plant material. This low-grade coal is lignite.

Sediment . . . erosion . . .badlands...



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The curious landscape Clark described resulted from erosion of the Fort Union Formation.

Altitudes near Terry range from 2200 to 2500 feet above sea level; the climate is semiarid. About 65-55 million years ago, however, vegetation grew abundantly here in a moist, subtropical climate near sea level.

Rivers flowing eastward from the mountains toward the inland ea deposited sand, silt and mud.

Woodlands, grasslands, and swamps were interspersed in the area. As plants in the swamps died their remains accumulated and slowly turned to peat.

When the rivers meandered or flooded, layers of sand, silt and clay buried the partially decomposed vegetation (peat) in the swamps.

Through geologic time the clay, silt and sand became mudstone, siltstone and sandstone, respectively. The peat became coal.

Image courtesy of The Field Museum, photographer John Weinstein ©1991

Photo by Ginette Abdo, MBMG

Sandstone and clinker of the Fort Union Formation tend to resist erosion; they often cap hills and buttes in the area. The finer-grained siltstone and mudstone of this formation erode more easily.

Rivers and seasonal streams cut through the flat-lying rocks, forming the canyons, ravines, gullies and hoodoos typical of a badland landscape.