A REPORT ON

The Geology of Devils Tower National Monument

By William L. Effinger

U. S. Department of the Interior
NATIONAL PARK SERVICE
FIELD DIVISION OF EDUCATION
Berkeley, California
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FOREWORD

This paper, the Geology of Devils Tower National Monument, is one of several prepared by a special research group employed under the Civil Works Program of 1933-34, by the Field Division of Education, National Park Service, Berkeley, California. Its purpose is to satisfy specialized needs existing in the National Park Service and it must not, therefore, be judged or regarded as a complete statement of the subject with which it deals.

The objective of this paper is the compilation of such pertinent information as will be helpful in the preparation of geological museum exhibits at Devils Tower National Monument and more specifically to outline the story to be interpreted by such exhibits. It is thus designed to aid museum preparators and Park Naturalists. For this reason the paper stresses those major geological features connected with the formation of Devils Tower and the generalized geology of the area surrounding it. Consequently, some readers may be disappointed in the paper, because of its limited scope; or may discover the omission of certain features which were not considered significant in the interpretation of this very specific feature of the landscape. Nevertheless, such interest has been manifested in the group of research papers, of which this is a part, that it seems worth while to make some of them available in the office mimeographed form. Not the least valuable feature of the paper should be its bibliography.

The format of the paper has been slightly modified from customary scholarly standards in order to save time and expense in mimeographing. Footnotes have been virtually eliminated and citations and comments are included in parentheses in the body of the text.

The mimeographing of this paper is made possible by assistance provided by the California State Emergency Relief Administration.

A REPORT ON
THE GEOLOGY OF DEVILS TOWER NATIONAL MONUMENT

PURPOSE AND SCOPE

This report presents the results of a search of geological literature for important information concerning the character, structure, field relations, petrography, geological history, and theories as to the origin of Devils Tower. Much of the material presented is in the form of abstracts. Frequent references are made to original sources of information, and a bibliography of the more important literature dealing with the subject accompanies the report. Special emphasis has been placed on information which might be used in developing a museum story of this monument.

Extensive use was made of the Matthew Library, the Geology Library, and the Main Library of the University of California. Members of the faculty of the Geology Department of the University of California have been consulted concerning the more dubious phases of the subject.

LOCATION AND PHYSIOGRAPHY

Devils Tower is located in Northeastern Crook County, Wyoming, on the Belle Fourche River. It is situated in that group of hills, lying principally in South Dakota but extending westwardly into Wyoming, known as the Black Hills. This group of hills, rising several thousands of feet above the surrounding northern Great Plains, constitutes an outlying member of the Rocky Mountain System. The hills have been carved from a dome-shaped uplift of the earth's crust, and consist largely of rocks which are older than those forming the surface of the Great Plains. The length of this elevated area is about one hundred miles and its greatest width is fifty miles. It is believed that about the same time the uplifting of these beds occurred, igneous activity became operative, resulting in the intrusion of numerous igneous bodies assuming various shapes. Where they cut the older rocks (Algonkian) consisting of schists and slates tilted on end, and where the lines of least resistance lie in an approximately vertical direction, a great profusion of dikes conforming with the strike and dip of the slate are formed. When these eruptives reached the Cambrian and later formations, the lines of least resistance lay in a horizontal direction, and eruptives, on encountering the heavier members of these formations, found it easier to insinuate themselves between the easily cleavable shales and sandstones than to break through the heavy overlying rocks. Therefore the predominant type of intrusion in the Cambrian is the intrusive sheet. In the higher formations especially, if the intruded mass has been large and the force of intrusion great, not only has the igneous rock been spread out between the sediments, but it has domed up the overlying formations, producing a laccolith.

The old dome-shaped uplift of the Black Hills has been truncated by erosion so that the salient features of the present topography consist of concentric ridges and valleys carved from strata of varying degrees of hardness. Protruding above these ridges and valleys are the denuded igneous bodies which, being more resistant to erosion than the surrounding sediments, stand out as prominent features of the landscape. The most spectacular of these igneous masses, even though smaller in size, is Devils Tower, which rises 600 feet above its base of rounded hills, being visible for many miles. Because of its unique beauty and its prominence as a landmark during the days of early exploration, it was set aside as a national monument by Presidential Proclamation, September 24, 1906.

NAME AND DESCRIPTION

The name now generally applied to this elevation is Devils Tower. Newton (1880) states that the name appearing on the earliest map of the region is, "Bear Lodge, (Mato Teepee)", and this is the name used in most of the earlier papers.

Jenney (1880) described the Little Missouri Buttes and Devils Tower as seen from the summit of Warren Peaks as follows: "To the west some twenty miles away, Bear Lodge Butte (Mato Teepee) and the Little Missouri Buttes appear in line. From this distance the former resembles in appearance the huge stump of a tree, its surface curiously striated vertically from top to base, and being perched on the crest of a high, flat topped ridge, it becomes a very prominent landmark, which once seen, is so singular and unique that it can never be forgotten. Although the Bear lodge country is an elevated region, and the different streams have a considerable fall before reaching the Belle Fourche, yet the topography is quite peculiar in the prevalence of long, flat-topped ridges or mesas between the narrow and deep valleys and canyons of the creeks. This is due to the resistance to erosion offered by hard and continuous strata of sandstone of the Jurassic and Cretaceous formations, which are here almost horizontal in their bedding, with a gentle slope away from Warren Peaks."

Newton and Jenney state that "Bear Lodge" was not reached by the Warren expedition, but that while the Raynolds expedition was in the vicinity of the Little Missouri River two attempts, the last successful, were made by Mr. Hutton to reach it. Since he recorded no particular description of it, Newton and Jenney's examination in 1875, "had all the charm of novelty. Its remarkable structure, its symmetry and its prominence made it an unfailing object of wonder. It is a rectangular obelisk of trachyte with a columnar structure, giving it a vertically striated appearance and it rises 625 feet, almost perpendicular, from its base. Its summit is so entirely inaccessible that the energetic explorer, to whom the ascent of an ordinarily difficult crag is but a pleasant pastime, standing at its base could only look upward in despair of ever planting his feet on the top."

Russell (1896) also remarks on the inaccessible character of the summit. "The strongest and most experienced mountain climber must pause when he has scaled the rugged cliffs which form the immediate base of the tower and gains the point where the individual prisms make their abrupt curve and ascend perpendicularly. Beyond that point no man has ever reached, and it is safe to say, never will, unaided by appliances to assist him in climbing." Jaggar, (1901, footnote p. 255) states in regard to the ascent of Devils Tower that by 1901 such appliances had been recently used. "With the aid of iron bars driven into the angle between two sloping columns, a rude ladder was constructed and ascent to the summit was made;" a fact attested by a small flag, visible from below which was left on the highest point of the tower.

Russell (1896) in his work on the igneous intrusions of the Black Hills has given a vivid description of the tower. "When Mato Teepee is seen from almost any locality in the valley of the Belle Fourche within a radius of several miles, one is not only forcibly impressed by the grandeur of the monumental form that dominates the landscape, but is delighted by the brilliant and varied colors of the rocks forming the sides of the valley and the immediate base of the tower. The Red Beds in the lower portion of the river bluffs show many variations of pink and Indian red, and have been sculptured into architectural forms of great beauty. The less brilliant Jurassic sandstones resting upon them and forming the upper portions of the bluffs, serve to carry the eye from the rich colors below to the dark forest of pines that grow above and to the still more somber precipices of the great tower which always appears in bold relief against the sky."

Darton (1909) describes Devils Tower as one of the most conspicuous features of the Black Hills province. It is a steepsided shaft rising 600 feet above a rounded ridge of sedimentary rocks, which in turn lie 600 feet above the Belle Fourche. Its nearly flat top is elliptical in outline, with a north-south diameter of more than 100 feet and an east-west diameter of about 60 feet. Its sides are strongly fluted by the great columns of the igneous rock and are nearly perpendicular except near the top, where there is some rounding, and near the bottom, where there is considerable outward flare. The base merges into a talus of huge masses of broken columns lying on a platform of the lower buff sandstone of the Sundance formation. Lower down are slopes of Spearfish red beds, which present high cliffs to the east, on the bank of the Belle Fourche. All the strata lie nearly horizontal, with a slight downward deflection toward the center of the igneous mass. In the lower ridges northwest of the tower the strata are somewhat tilted, but apparently this is due to undermining by erosion on the adjacent gulches. The great columns of which the tower consists are mostly pentagonal in shape, but some are four or six sided. The average diameter is six feet, and in general the columns taper slightly toward the top. In places several columns unite in their upper portions to form a large fluted column. The columns are not perpendicular, but slope inward toward the top, the angle being 4° to 5° on the west side and 10° to 12° on the east side. They are not much jointed but are marked horizontally by faint ridges or swellings, which give the rock some appearance of bedding, especially toward the top of the tower. Near the top the rock is much jointed and irregularly fissured, and is more or less decomposed, crumbling into rounded fragments. The color at the top is brownish, mottled with dirty yellow-green, due to lichens. In the lower quarter or third of the tower, the columns bend outward and merge rapidly into massive rock, which toward the base, shows but little trace of columnar structure. This massive rock circles the tower as a bench extending out for 30 to 40 feet. It is strongly jointed, part into irregular prismatic forms, and part into rough, coarse layers. On the southwest face the long columns curve outward over the massive basal portion and lie nearly horizontal. The rugged pile of talus extends high up the lower slopes of the massive bench at the base of the tower, and also far down the adjoining slopes of the sedimentary rocks. In places it rises as a low ridge not far from the base of the tower, the fragments falling from the higher cliffs having bounded some distance away. At one point on the platform a short distance south of the tower, a low hill of porphyry shows a surface of 30 or 40 feet of massive rock, which may possibly be in place, and a low cliff of massive porphyry a few rods southeast of the base of the tower strongly suggests igneous rock in place.

DEVILS TOWER AGGLOMERATE

At the edge of the main talus slope on the west-southwest side of the tower is a small, elliptical, grassy hill encircled by talus. It is about 150 yards long, trends west-southwest and consists of agglomerate which does not appear elsewhere in the vicinity, although it may underlie some of the talus. A trench was excavated in the hill in order to obtain specimens of all the fragments and of the matrix, the last appearing to be a decomposed porphyry. The most conspicuous fragments of the agglomerate are granite, in either rounded or angular forms, varying in size from small pebbles to boulders one or two feet in diameter. The rounded fragments have a somewhat faceted character, unlike the smooth polish of stream-rolled material. A limestone boulder of characteristic carboniferous habit, containing spirifers and other fossils, about a foot in diameter, was found to be encased in a shell half an inch thick, which could be broken away, parting smoothly from the rounded surface beneath as if the mass had been subjected to calcination by heat. Except for the greater variety of contained fragments, this agglomerate is essentially like the one found in the Little Missouri Buttes. The Devils Tower agglomerate contains in abundance two varieties of carbonaceous shales, which, according to Jaggar, are of a type not known to occur below the Lower Cretaceous and Benton terranes, which are stratigraphically higher than the present location of the agglomerate. This is believed by Jaggar to be strong evidence in favor of the Devils Tower intrusion being an offshoot from the Little Missouri Buttes, for the magmas giving rise to the Little Missouri Buttes are known to have intruded the Benton carbonaceous shales. Darton (1909), however, discredits this evidence, stating that such carbonaceous shales occur at intervals in the formations as old as the Minnelusa (Carboniferous).

It seems most natural to suppose this agglomerate to represent some of the first material to be injected in the sedimentary beds to form the igneous mass of Devils Tower. The magma, ascending through the underlying formations, picked up and carried along pieces of these formations, the heat partially fusing and altering the outer margins; but finally, with the cooling of the igneous material, the fragments were left as inclusions in the magma.

CHARACTER OF ROCK COMPOSING DEVILS TOWER

The igneous rock forming the main portion of the tower was identified by Pirsson (1894) as a phonolite rich in soda feldspar. A petrographic study was made of this rock by Albert Johannsen, a description of it appearing in Darton and O'Hara's work in the Devils Tower Folio. Johannsen refers to this rock as phonolite porphyry. "Megascopically the rock is coarsely porphyritic and is medium gray in color. It consists of large, white or colorless, short thick crystals of feldspar and minute, dark-green pyraxenes, in a gray, aphonitic groundmass. The feldspar crystals vary from one-eighth to one half inch in diameter although most are less than one quarter inch."

The microscope reveals the phenocrists to be feldspar, pyroxene, apatite, and very little magnetite and titanite. No nephalite phenocrists are found. The feldspar, a soda rich orthoclose, is in general fairly fresh, although somewhat altered along cleavage cracks to kaolin and isotropic zeolites. The pyroxene, varying from perhaps one-quarter to one-half as much in amount as the feldspar, occurs in short, thick crystals, is very fresh, and almost invariably shows zonal structure. It is green in color and as a rule darkest around the edges. The centers are augite and the outer zones are aegirite. The apatite phenocrysts are short, thick, colorless prisms or hexagonal basal sections. Magnetite occurs in a few irregular grains; and titanite, in rectangular or lozenze-shaped crystals, most of which are twinned, is rare. Apatite is present in small amounts as an accessory.

The groundmass consists of small orthoclase laths in subparallel position and shreds and needles of aegirite, with small clouded crystals and anhedrons between. These clouded spaces are for the most part indeterminate; some of them are clear and colorless and definitely alpali feldspar, but about half of them are brownish and clouded. Scattered through the groundmass, in some of the rock, is magnetite in exceedingly small cubes. There is much secondary material--calcite, kaolin, chlorite, analcite and ananisotropic zeolite. Very commonly a calcite center is surrounded by an analcite rim, the whole being a cavity filling. Some of these secondary products have definitely been derived from the feldspars.

Analysis of Phonolite Porphyry From Devils Tower

SiO	61.08%	H_2O	2.21%
Al2O3	18.71	TiO_2	.18
Fe2O3	1.91	SO_3	Trace
FeO	.63	Cl	.12
MgO	.08	MnO	Trace
CaO	1.58	BaO	.05
Na_2O	8.68		99.86%
K_2O	4.63		

COLUMNAR STRUCTURE

One of the most notable features of Devils Tower is its excellently developed columnar structure. Therefore it may be interesting to note briefly how these structures may be formed. (Pirsson, L.V. and Knopf, A. 1926, p. 166).

As a body of magma cools and crystalizes into rock it is subject to extensive contraction, which causes great fissures and cracks to form, dividing the mass into variously shaped blocks. Sometimes these cracks form rudely cubic or rhomboidal blocks, commonly shown in granites; or they may form platy partings, making the rocks look much like bedded sediments; sometimes the planes of cracking are curved, forming concentric or spheroidal masses; or in other cases columnar structures are formed.

In columnar structure the whole mass is made up of columns, regularly fitted together and from a few inches to several feet in diameter and from one foot to many feet in length. THe columns always form perpendicularly to the greatest extension of the main cooling surface of the igneous mass; hence in a lava flow, intrusive sheet or laccolith, the columns would be nearly vertical - when in a dike they tend to be more nearly horizontal. It is believed that when a homogeneous mass is cooling slowly and regularly, centers of cracking seem to occur on the cooling surfaces at equally spaced intervals. From each central interspace these cracks radiate outward at angles of 120 degrees from each other. These intersecting cracks produce regular hexagons, and the cracks penetrating downward make columns. This regular arrangement produces the greatest amount of contraction with the least amount of cracking, providing the centers of cooling are equally spaced. But as the contractional centers are not always equally spaced, 3, 4, 5, 7, or 8 sided columns occur. The columns contracting lengthwise, break into sections as they form. This same principle is also shown in drying mud flats where the clay cracks into polygonal shapes, or again in the prisms of drying and contracting starch. Such columns, no matter how regular their appearance, are not crystals but pieces of rock, and should not be confused with prisms produced by the crystalization of certain minerals such as quartz, beryl, etc., which are formed by an entirely different process.

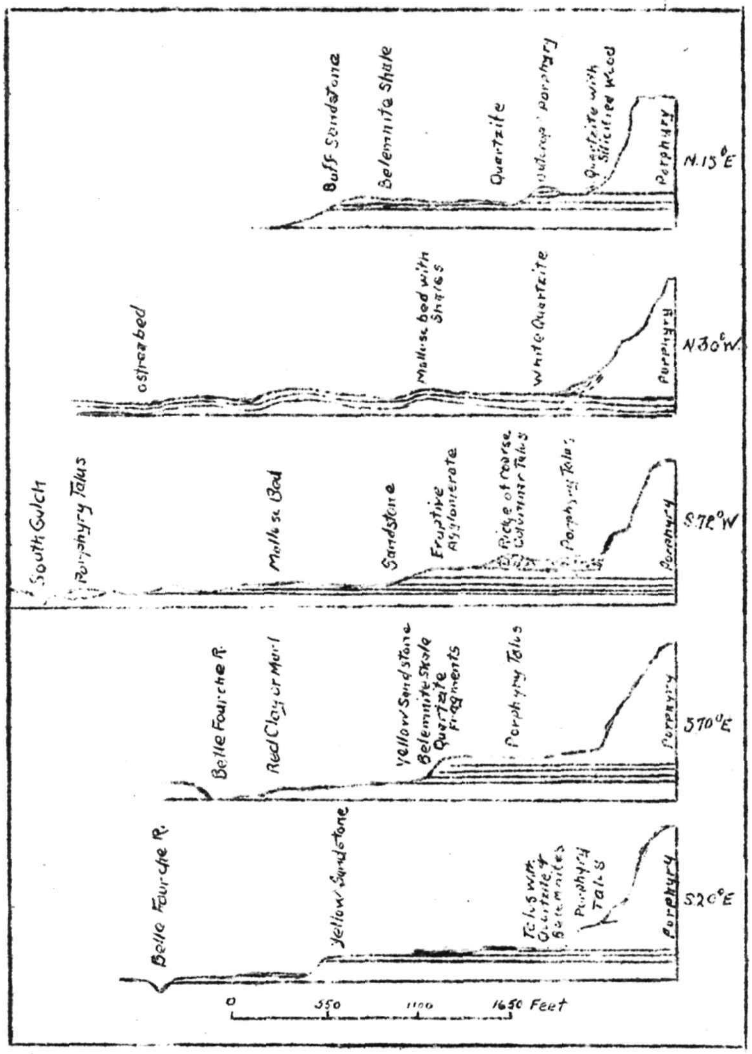
STRATIGRAPHY

Devils Tower is underlain by Jurassic beds stratigraphically and topographically lower than those on which the Little Missouri Buttes rest. A hundred yards northwest of the tower, following the narrow divide between the encircling streams, a white, fine-grained quartzite outcrops in the characteristic greenish soil of belemnite shale. A hundred yards farther west along the divide a shell bed (Tancredia) occurs, carrying concretions and dipping due south about 48 degrees. Above and below are green shales, and the strike of the outcrop seems to curve. A little farther west oyster beds appear, dipping 34 degrees **north,** 35 degrees west, but these beds followed west along the strike, become more nearly horizontal under the Little Missouri bench of horizontal strata. At the foot of this bench are green and purple clays capped by buff sandstone.

The accompanying sections show the structure of the platform beneath Devils Tower, which in general consists of level bedded Jurassic sandstone, marls, shale, and quartzite; any variations from horizontality being rather of the nature of dip toward the tower than away from it. North 25 degrees west from the tower about 1000 yards occur two quartzite ridges showing scattered fragments of quartzite on the side toward the tower, but without sufficient outcrop to give clear evidence of dip. About the same distance north 55 degrees west in the gulch the buff sandstone appears, dipping two degrees due north. Two hundred yards due north of the tower there is an outcrop of quartzite, very fine in texture, so as to appear almost like flint, of gray color, with a vertical lamination trending east and west, and 25 yards nearer the tower, adjacent to the quartzite, occurs a large mass of porphyry that appears to be an outcrop. On a small knoll north 75 degrees east of the tower, only thirty yards from the porphyry talus, directly at the foot of the great basal bench, there is an outcrop of quartzite carrying fossil fragments of silicified wood, and this quartzite is abundant here in the roots of fallen trees, indicating that this bed is the uppermost member of the Jurassic strata that underlies the eruptive mass. This quartzite undoubtedly occurs higher than the belemnite shales that cover the ridge on the southern side of the tower. The quartzite varies, in places consisting of distinct clastic grains, and elsewhere being of fine-grained aphanitic texture. The platform bench northeast of the tower is not so long as on the southwest side. It extends northwest for some 2000 yards, and the greenish belemnite shales here crop out below the quartzite. The best point of view for observing the synclinal sag under the tower is the road near Ryan's Ranch on the eastern side of the Belle Fourche Valley. From this point the talus of porphyry fragments from the tower to the very border of the stream may be best observed, and on either side the sandstone is seen to dip inward gently, forming a V-shaped sag of wide angle in which the apex is immediately below the great columns.

RADIAL CROSS SECTIONS OF DEVILS TOWER

Modified From Jaggar



The Jurassic section is approximately as follows from the base of the tower down: (Jaggar 1901, p. 260).

Quartzite
Tancredia limestone
Smoky, fine-grained limestone
Belemnite shales
Oyster bed
Bluff of tender buff sandstone, sometimes pink
Green shales
Thick shell bed, forming a hard band
Buff marl
Gypsiferous red beds (marl)

GEOLOGICAL AGE OF THE INTRUSIVES

The geological age during which the intrusive bodies of the Black Hills were formed may be stated only in the most general terms. The Bear Butte and Little Missouri Buttes laccoliths were intruded into Benton Cretaceous and were unquestionably covered by Niobrara limestone. Jenney found pebbles of Black Hills porphyries in the conglomerate at the base of the White River beds (Oligocene) to the southeast. This would limit the time of intrusion to that span of time between the Upper Cretaceous and the Lower Oligocene. Darton (1909, p. 76) states that the igneous intrusions probably occurred during early Tertiary time - or possibly in latest Cretaceous time - contemporaneously with the general uplift of the Black Hills.

THEORIES OF ORIGIN

There is a good deal of uncertainty concerning the mode of origin of Devils Tower and the type of igneous body it represents. Newton and Jenney noted the extreme difference in the appearance of Devils Tower with its steep-sided shaft in contrast to the rather uniformly conical shape of most of the other igneous masses of the region. They further state, concerning the igneous bodies of the Black Hills, that the peaks appear to be merely pointed or conical waves of igneous rock forced upward through the sedimentary strata which are found disrupted and turned up around them only in their immediate vicinity. The metamorphism of the upturned strata is limited in extent, reaching only a few feet from their contact with the igneous rocks. There seems to be no evidence of any overflow of the igneous matter, but it is confined exclusively to the peaks. The view that they are the cores to extinct volcanoes or centers of igneous overflow is scarcely warranted by the observed facts. It would appear that the igneous peaks, instead of being the product of violent volcanic action, are situated at a great distance from the central and maximum region of igneous action, and that instead of the material being ejected with great violence and at such a temperature as to cause it to overflow readily, it was forced through the sedimentary strata under great pressure and at such a temperature as to make it plastic rather than fluid. The occurrence of these trachytic peaks appears like a great postular outbreak on the surface of the northern end of the Black Hills, whereby the deep-seated igneous forces were relieved, or like the appearance of bubbles on the surface of a kettle of boiling tar.

Carpenter (1888) interpreted Devils Tower to represent a volcanic plug, being the duct through which the subterranean magmas passed to higher level in the earth's crust. Russell (1896) proposed the name plutonic plug for the intrusive bodies of the Black Hills, stating that they differ from the laccoliths described by G. K. Gilbert (1877) in the fact that the molten rock did not spread out horizontally among the stratified beds so as to form "stone cisterns", although some of the hills not thoroughly examined by him might reveal this structure with further study. "As they are composed of igneous matter forced into sedimentary strata and have a plug-like form, it will be convenient to call them plutonic plugs." Devils Tower is believed by him to represent an extreme type of plug, the part now remaining being an erosional remnant, where the arch of stratified rock which once surmounted the summit of the mass has been completely removed and the surrounding strata eroded away.

Pirsson, (1898, p. 582) in commenting upon Russell's view, states, "It is impossible to conceive that the tall shaft-like mass of Mato Teepee, with a vertical columnar structure whose columns are several hundred feet long, can be a volcanic plug in a condition anywhere near approaching its original horizontal diameter. The mechanics of the jointing of igneous rocks forbids such a supposition, and we must believe that it represents only a still uneroded fragment whose vertical walls are produced by the columnar structure of a mass which formerly was of much greater lateral extension and possibly of laccolithic form".

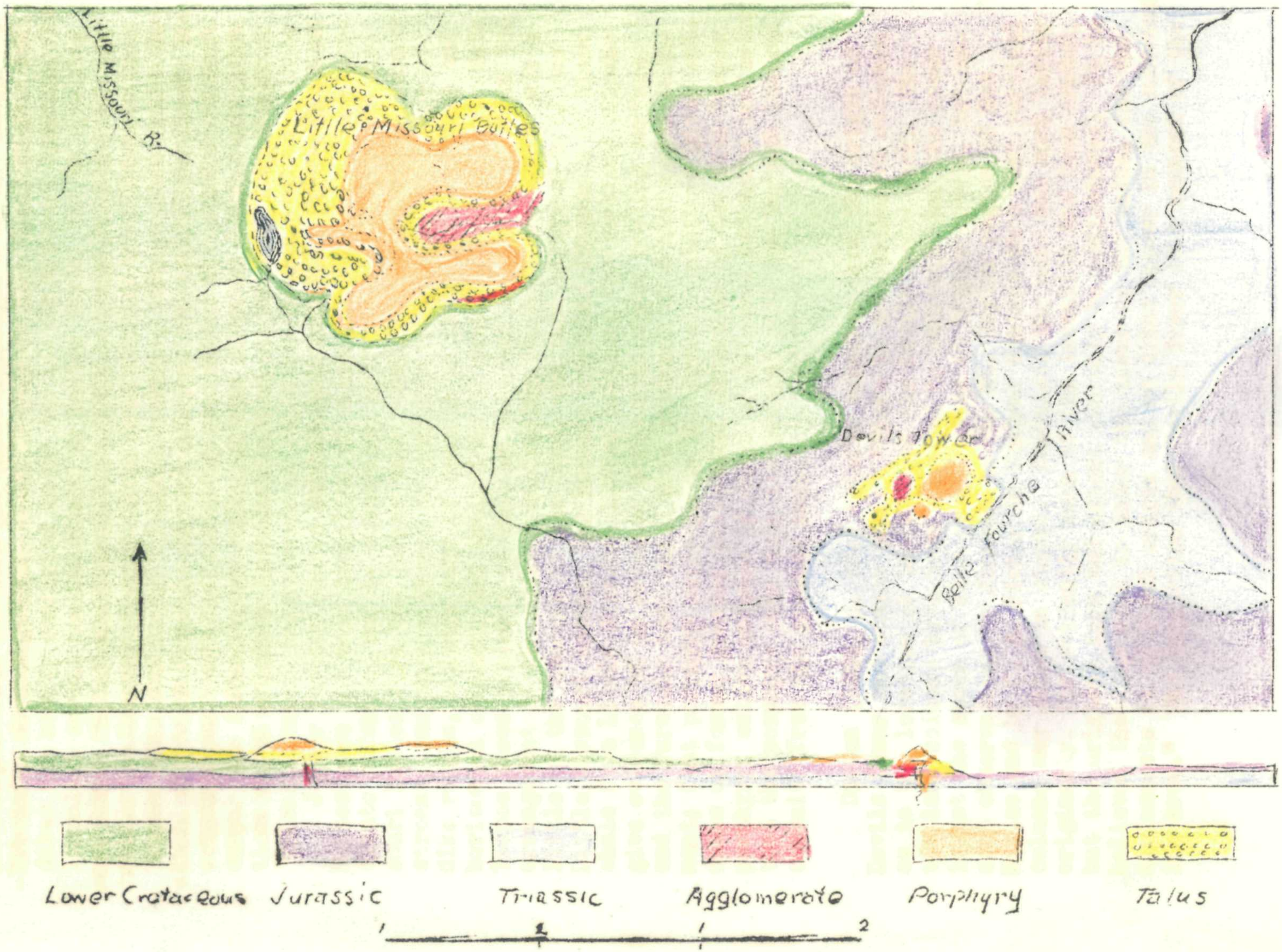
Jaggar (1901) adheres to the theory of a laccolithic origin for Devils Tower, believing it to have been at one time an eastward extension of the Little Missouri Buttes laccolith and that erosion has removed the connecting mass. He states it is probable that the agglomerates were the first and most fluid injections of a magma which rose rapidly and with some violence through fractures from Algonkian to Cretaceous rocks. The conduits were dikes now nearly concealed under the Little Missouri Buttes. The laccolith spread southeastward in Benton shale, met an opposing northwest dip of the Warren Peak flanks, broke downward through the lower Cretaceous sandstone, and formed a subordinate Mato Teepee laccolith in soft Jurassic strata. The present upper surface of Devils Tower is smooth and possibly represents nearly the actual upper contact, from which the shales have been weathered away. The following geologic section shows an ideal reconstruction of the original laccolithic mass as postulated by Jaggar.

Jaggar further states that "the proofs that Little Missouri Buttes were the main laccolith of which Mato Teepee was a subordinate offshoot, may be summarized as follows: The Little Missouri Buttes form the larger mass today, encircled by the larger streams, and show evidence of conduits beneath in the shape of dike ridges, a large mass of breccia at the base, irregular and horizontal columns, and inclusions of granite in porphyry. Mato Teepee shows evidence of smaller size and lenticular form in the arrangement of the smaller encircling streams, and shows only a little of the breccia at the base, and that on the side of the Little Missouri Buttes; the breccia contains fragments of black shale from Little Missouri Buttes horizon; the vertical columns give evidence of an extended horizontal upper cooling surface, and the Jurassic beds below give evidence of a horizontal basement; flat porphyry outcrops on the Jurassic platform gives evidence of former greater horizontal extension of the Mato Teepee porphyry; entire absence of dikes or deformed sediments indicates that the porphyry came into its present position through lateral conduits from the greater mass."

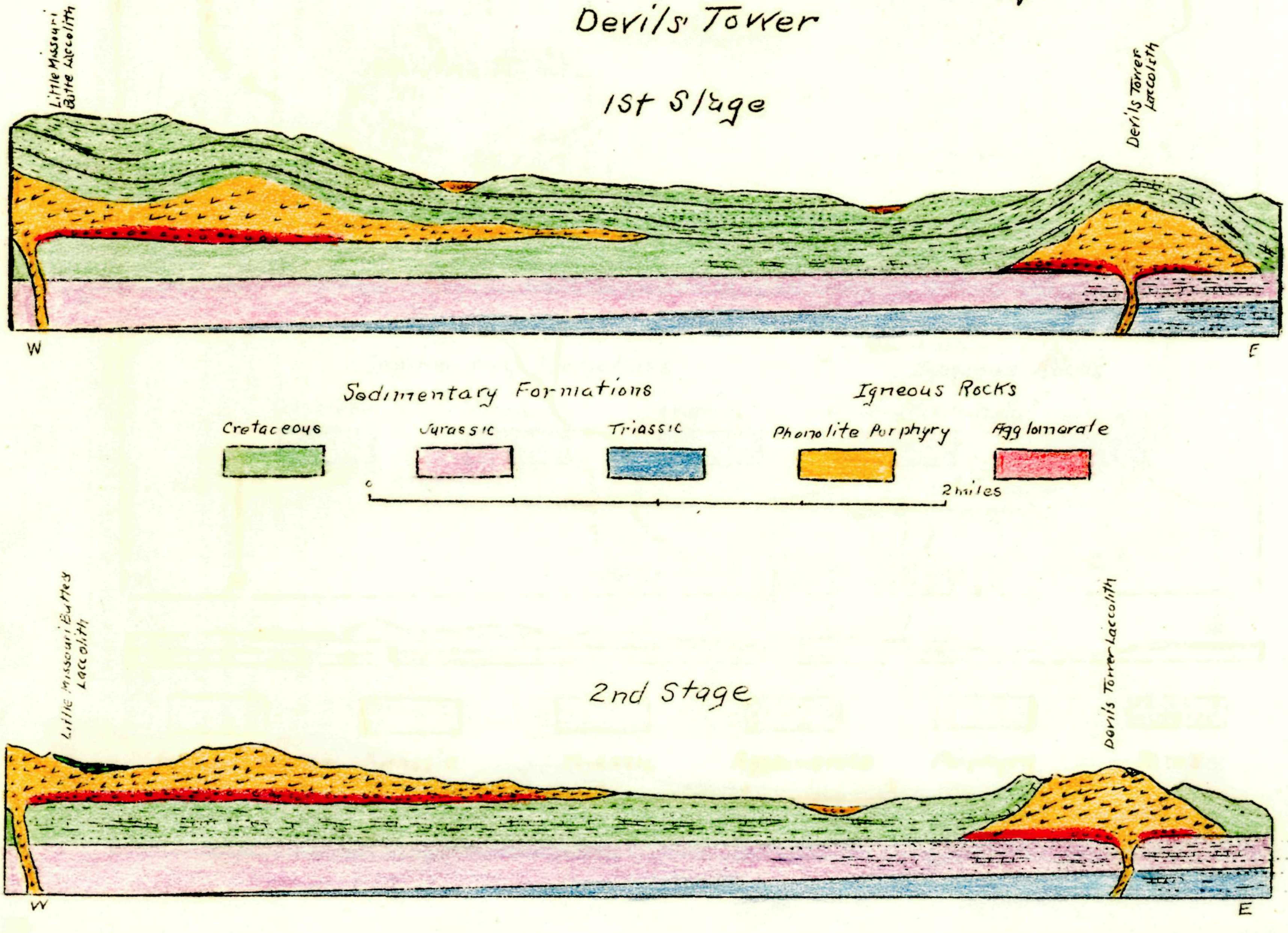
Darton (1909, p. 69.) briefly comments upon the origin of Devils Tower and states that: "There is no conclusive evidence as to the location of the vent of the Devils Tower rock. The vertical columns have been supposed to indicate that the tower is not the stock of flow or intrusion at higher levels, but recent observations by Johnson in the Mt. Taylor region of New Mexico and by C. A. Fisher in Central Montana show that vertical columns may exist in stocks. Doubtless the mass was much larger originally, for evidently much of the laccolith has been eroded, but the original form and extent can only be conjectured. It is believed that the vent is under the tower or the talus, for the agglomerate is of local origin and no dikes appear in the surrounding area." The suggestion that Devils Tower is a remnant of the southeast end of a laccolith extending from the Missouri Buttes, involves an improbable amount of erosion and numberous other difficulties.

From a consideration of the evidence presented it would seem most reasonable to believe that Devils Tower represents a remnant of a laccolith, probably rather small in comparison with others of the Black Hills, and separate from the Laccolith of the Little Missouri Buttes. It would seem probable that the duct through which the igneous material was injected lies beneath the tower or the talus. The stages in the formation of Devils Tower according to this hypothesis might be represented diagramatically as is shown in the succeeding charts.

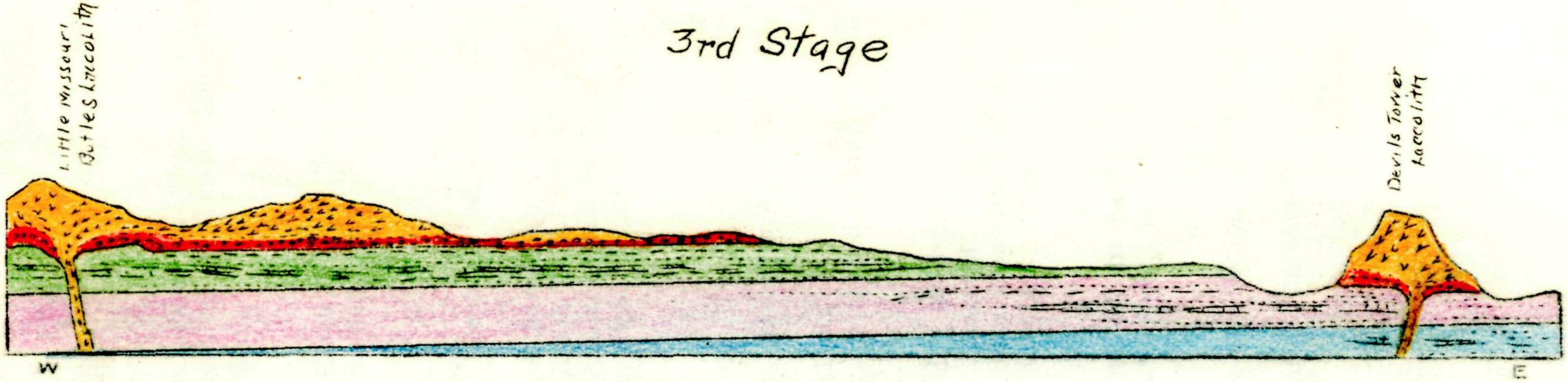
GEOLOGICAL SKETCH MAP & CROSS SECTION OF LITTLE MISSOURI BUTTES AND DEVILS TOWER

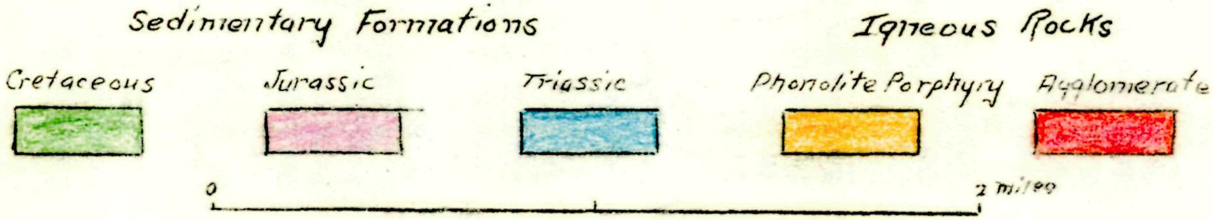


Hypothetical Cross Sections To Show Possible Origin of Devils Tower

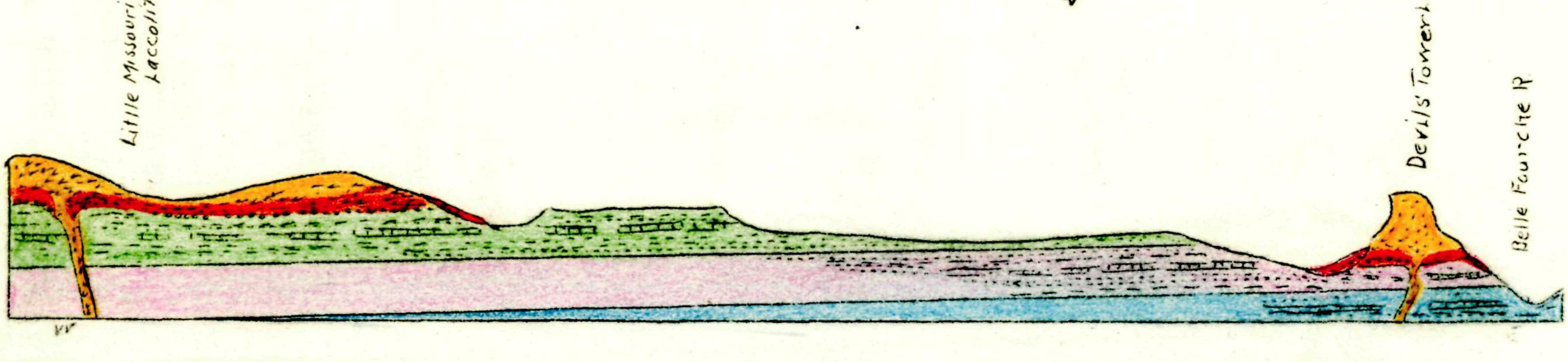


3rd Stage





4th + Present Stage



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