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Petroleum Geology of Paleozoic Rocks of Cordilleran Miogeosyncline: Talk for U.S.G.S. Petroleum Research and Resources Seminar, Dec. 12, 1974

By

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(Based on work in progress by E. K. Maughan, F. G. Poole, E. G. Sable and C. A. Sandberg, with technical support by G. E. Claypool and J. G. Palacas)

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The Paleozoic rocks of the Cordilleran miogeosyncline project, which will be activated in January 1975, is designed to evaluate the petroleum potential of one of the few remaining major unexplored onshore provinces--the eastern Great Basin and adjacent Sevier fold-and-thrust belt. In the next three years, we hope to provide a complete stratigraphic, tectonic, and petroleum source-rock analysis of the middle and upper Paleozoic rocks of this virtually untested area. The sites and tectonic settings of source-rock deposition will be determined, paths of possible oil migration into the adjacent Rocky Mountain Province will be traced, and possible stratigraphic and structural traps that may have retained oil within the Great Basin will be delineated. In addition to heading this project, I will be responsible for a basin analysis of the Devonian System. Barney Poole will be responsible for the Mississippian flysch, and he and I will collaborate on both the Devonian and Mississippian. Eddie Maughan will be responsible for the Permian. If you agree that the data and concepts presented here today have some merit, I hope you will support me in my efforts to increase our project staff, so that the Pennsylvanian and Silurian Systems can be tackled and similarly treated and so that our staff will have more time for preparing short topical reports of immediate economic interest.

It is my firm belief that some major oil companies have written off the eastern Great Basin largely because of a supposed excessive regional thermal gradient. I hope my remarks will help dispel this myth. Many independents have ignored this area because of the difficulty of compiling an adequate regional stratigraphic, tectonic, and structural framework for exploration. Our staff already has the capability for providing some of these data.

During the past year-and-a-half, three pilot source-rock projects have been under way; these will be combined into a single superproject in 1975. Eddie Maughan has been compiling data on source beds in the Permian Phosphoria Formation in northern Utah, western Wyoming, eastern Idaho, and southwestern Montana. His data support the concept of the Phosphoria having been a source for most of the Paleozoic oil in Wyoming and suggest that it may be an unrecognized source in western Montana. Barney Poole, assisted by me, has been studying source beds in the Mississippian to Lower Pennsylvanian flysch of the eastern Great Basin--in eastern Nevada, western Utah, and central Idaho. At the same time, Ed Sable has collected source-rock data on the equivalent intertonguing carbonaceous shale-and-limestone sequence on the platform to the east. With Poole's help, I have made a regional stratigraphic, faunal, and source-rock analysis of the Devonian and Mississippian Pilot Shale in western Utah and eastern Nevada. Conodonts were used not only to date the exact time of source-rock deposition to within the nearest half-million years, but also to provide environmental interpretations of facies and to determine the grade of incipient metamorphism based on conodont alteration colors.

Now, I would like to outline the results of our preliminary source-rock studies beginning with the Phosphoria and working down section.

PERMIAN PHOSPHORIA FORMATION

SLIDE 1

The Permian Phosphoria Formation contains two carbonaceous shale source beds--the Meade Peak and Retort Members. These shales were deposited in a neritic environment in the seaward part of an embayment onto the craton. The organic matter in them is believed to be largely of marine origin. The thickness and distribution of the lower shale--the Meade Peak--is shown by isopachs at 10-metre intervals. Superimposed are the isopleths giving the percent of residual organic carbon. You will note that the Meade Peak has a maximum thickness of 50 metres in the area south of the Snake River Plain and west of the leading edge of the Wyoming thrust-belt in southeastern Idaho and northern Utah. The isopleths show organic carbon values in excess of 8 percent in western Wyoming and greater than 5 percent in northern Utah. The Meade Peak is much thinner and less organic rich north of the plain, where it is not regarded as a potential source bed.

SLIDE 2

Shale deposition was interrupted by a regression during which chert was deposited. During a second transgression, the Retort Member, shown here, was deposited. You will note that the area of maximum thickness and greatest organic richness has shifted to the area north of the Snake River Plain in southwestern Montana. The thinning of the Retort along the Idaho-Wyoming line resulted from pre-Triassic erosion. The Retort is not regarded as a potential souce bed in that area. North of the plain, however, the Retort contains as much as 12.7 percent residual organic carbon and has been retorted to yield 20 gallons of oil per ton.

We believe that the high organic carbon values in the Phosphoria support the Meade Peak being a source for oil that migrated a long distance eastward into all parts of the Paleozoic in Wyoming. Analogously, the Retort may have been a source for oil that migrated eastward in southwestern Montana.

MISSISSIPPIAN FLYSCH

SLIDE 3

Turning to the Mississippian flysch, we see a totally different depositional pattern, as demonstrated by this slide, which shows the Lower Mississippian part. The flysch, which has a combined total of as much as 4,500 metres for the Lower and Upper Mississippian parts, contains carbonaceous shales such as the Chainman that yield as much as 3 percent residual organic carbon and 200 parts per million soluble hydrocarbons. The lower part of the flysch, shown on this slide, has a maximum thickness in excess of 6,000 feet or about 2,000 metres. The flysch, comprising neritic and bathyal marine mudstone, siltstone, sandstone, conglomerate, and impure limestone, was deposited in a rapidly subsiding, elongate, structural foreland basin on the continental shelf between the stippled Antler Orogenic Highland on the west and the cratonic platform, shown by an open-stippled pattern, on the east. The major source of detritus was from the highland on the west. The organic carbon is composed largely of land-plant debris with minor contributions from marine plants.

SLIDE 4

The next slide shows that the Upper Mississippian flysch largely filled the foreland basin and spilled eastward onto the cratonic platform, where it intertongued with limestones. The area of flysch sedimentation occupies eastern Nevada and western Utah and extends northward into central Idaho.

Earlier in my talk, I promised to dispel the myth of excessive thermal gradient in the eastern Great Basin. Our observations of palynomorph and conodont alteration colors and coalification rank of woody debris indicate that maximum past temperatures in the flysch apparently increased progressively westward from less than 100° C to more than 300° C with many local variations. Admittedly there are many "hot spots," but we were impressed by the many "cold spots" and by overall low temperatures, about 100° C, in the eastern part of the flysch belt. By late Paleozoic time, heat induced by great sediment thickness alone was sufficient to generate and expel petroleum from source beds in some areas. Elsewhere either generation and expulsion or overcooking and thermal degradation occurred in Mesozoic and Cenozoic time when additional heat was induced by higher geothermal gradients and local magmatic and hydrothermal activity. The greatest deterrent to exploration probably is the fracturing of petroleum generation systems and of reservoirs by basin-and-range faulting. However, we believe that the processes of generation, expulsion, and migration may still be operative and hence may postdate the sealing of fractures in some areas.

DEVONIAN AND MISSISSIPPIAN PILOT SHALE

SLIDE 5

Continuing down the stratigraphic column, we reach the Mississippian and Devonian Pilot Shale, which is a complex of three rock bodies of different ages. Our organic carbon data indicate that only the lower unit of the Pilot, shown on this fifth slide, contains carbonaceous mudstone and limestone beds of sufficient thickness, areal distribution, and organic richness to merit consideration as source beds for petroleum generation. This map, drawn at 100-metre isopach intervals, shows the distribution and thickness of the lower Pilot, which was deposited on the miogeoclinal carbonate shelf in a rapidly subsiding basin centered near the Nevada-Utah line.

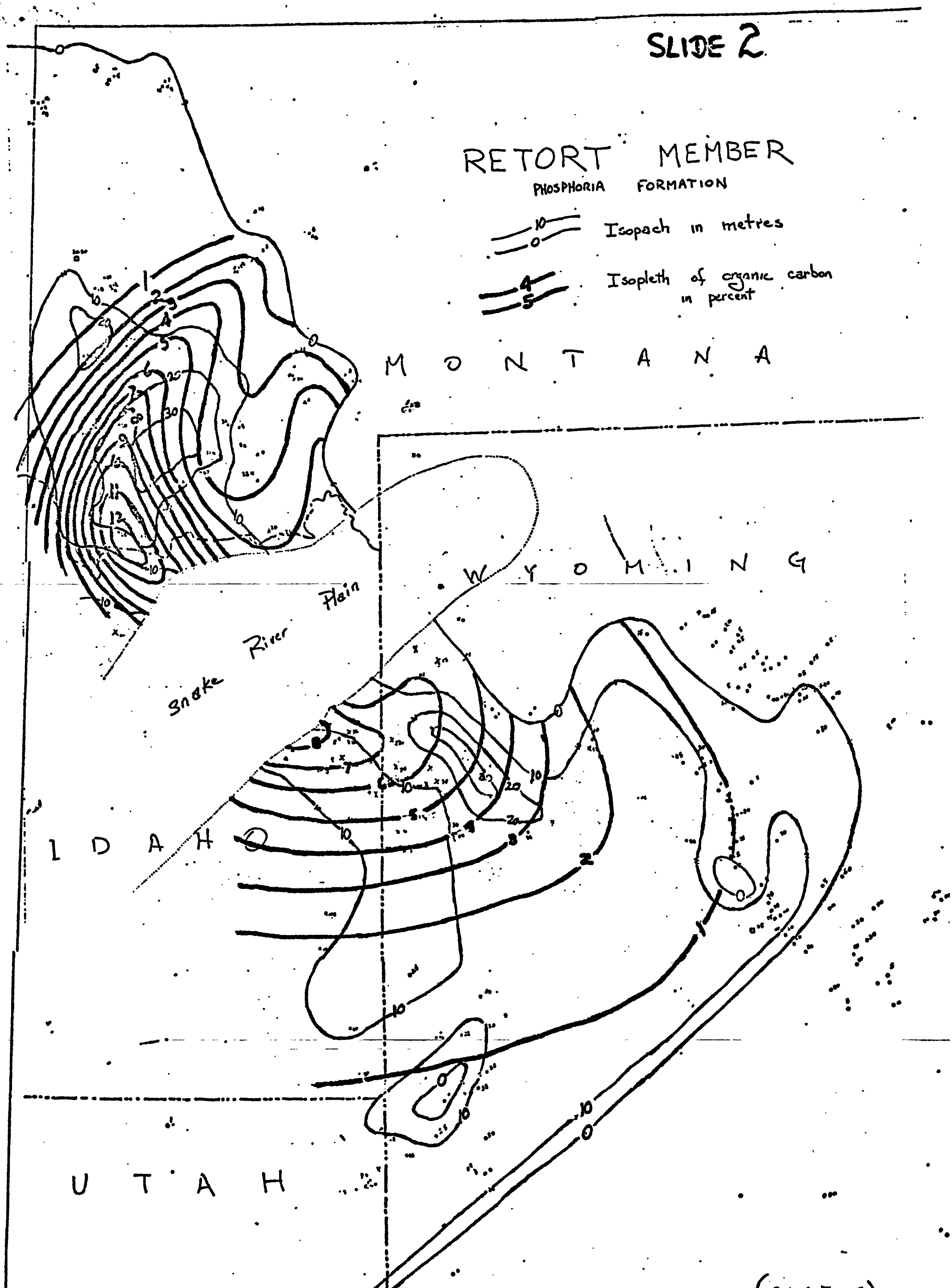
The area of promising source beds is shown by shading in the eastern part of the basin. At Little Mile-and-a-Half Canyon, this mudstone interval is 93 metres thick, has an average residual organic carbon content of 2.2 percent, and yields about 160 parts per million total soluble hydrocarbons. You will note that the Pilot basin is surrounded by shelf carbonate rocks. The line passing through Little Mile-and-a-Half Canyon locates the cross section shown on the next slide.

SLIDE 6

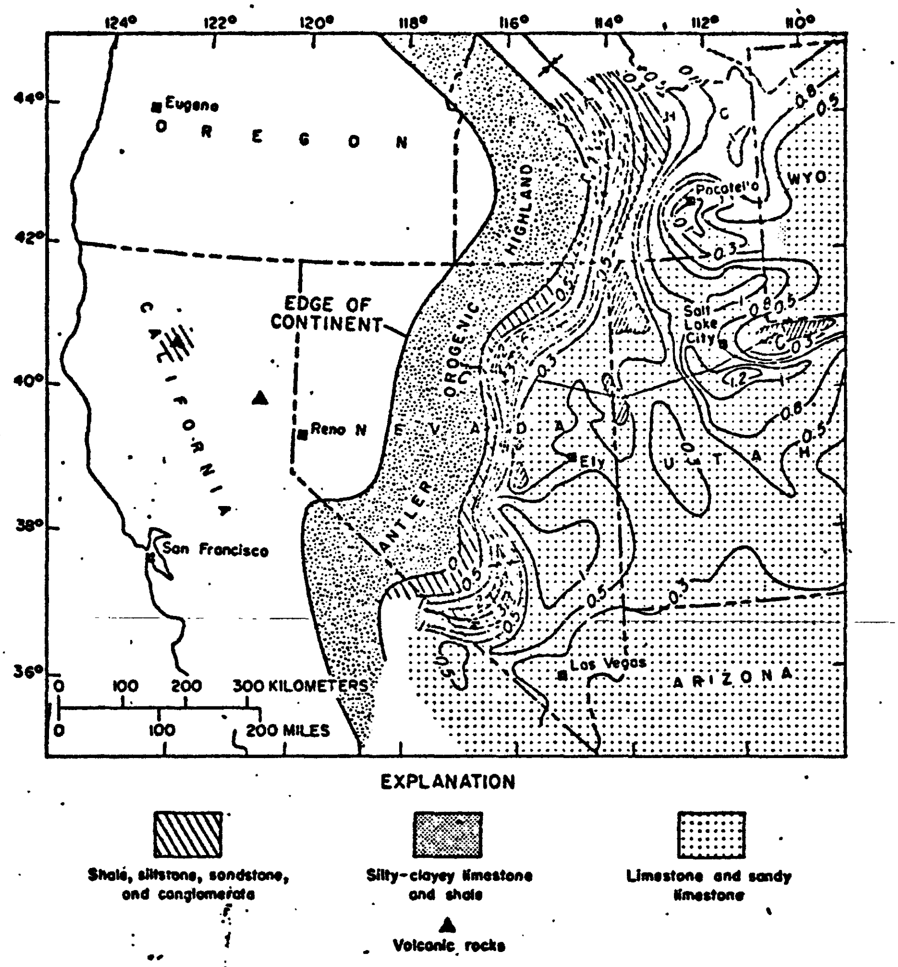
This cross section, using the time plane of a conodont zone for a datum, demonstrates how turbidites, debris-flow deposits, and shallow-water limestones of the lower Pilot intertongue and grade peripherally with the West Range, Devils Gate, and Guilmette Limestones. Again, note the interval of promising source beds in the eastern part of the basin. According to conodont alteration colors, these source beds have not been subjected to temperatures in excess of 90° C in Utah and 140° C in Nevada--further dispelling the myth of overcooking. We believe that these beds may have generated petroleum for distant eastward migration into the western Rocky Mountain region, just as the Phosphoria did in Wyoming. Furthermore, many local accumulations may have remained in western Utah. Next summer, we will focus attention on the intertonguing relations and nature of the hydrocarbons in the limestone belt in central Utah, shown on the east edge of this slide.

CONCLUDING REMARKS

A final slide [a Kodachrome, not included herewith] shows a scene that we hope will become commonplace in the eastern Great Basin--a well drilling in western Utah against a background of the Snake Range just across the Nevada State line. Not wildcatting like this, but thoroughly researched, scientifically sound exploration programs, based on the knowledge gained through our Paleozoic source rocks project, can turn this "last frontier" basin into a successful producing province.

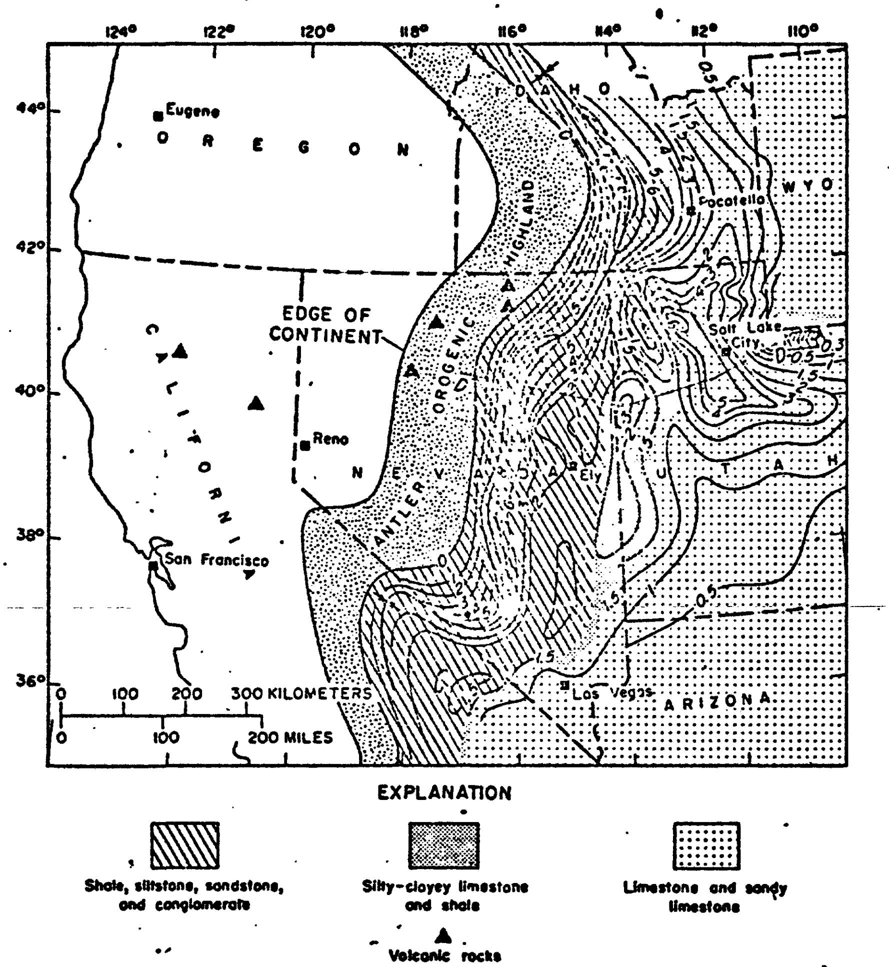

SLIDE 2
RETORT MEMBER
PHOSPHORIA FORMATION
Isopach in metres
Isopleth of organic carbon in percent
MONTANA
WYOMING
IDAHO
UTAH
Snake River Plain

SLIDE 3

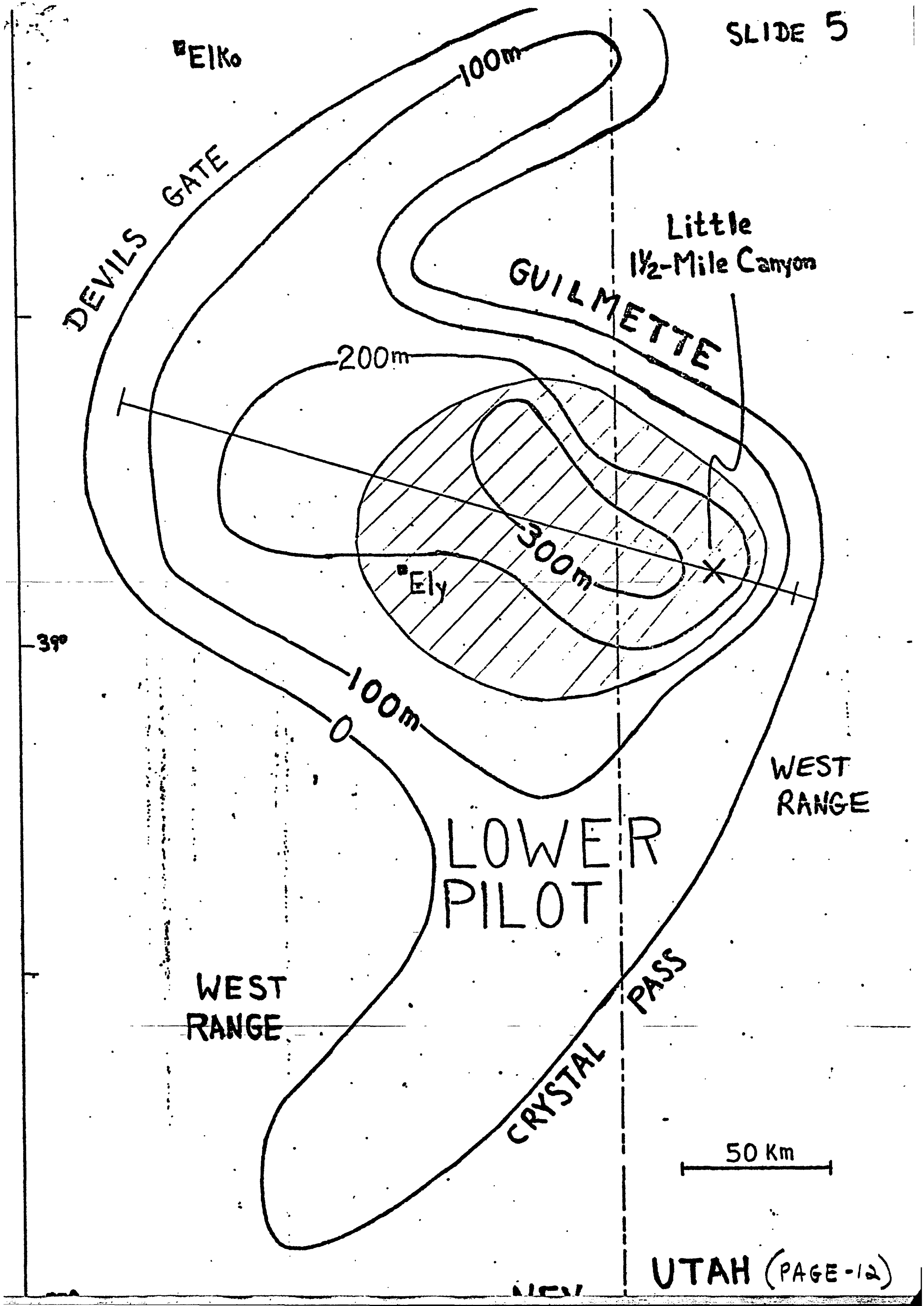


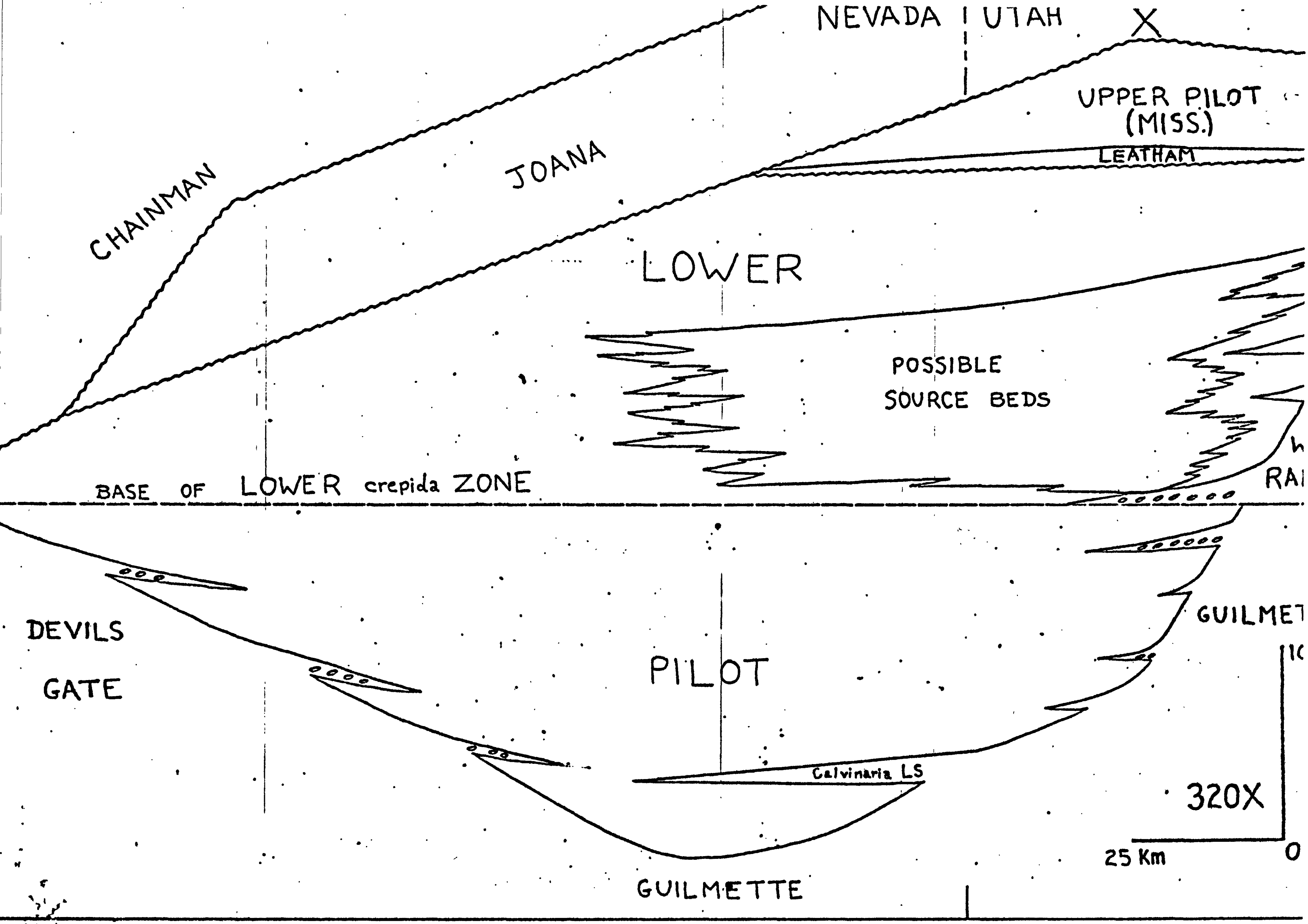
LOWER MISSISSIPPIAN

SLIDE 4



UPPER MISSISSIPPIAN


SLIDE 5
Elko
100m
DEVILS GATE
Little
1½-Mile Canyon
GUILMETTE
200m
300m
Ely
39°
100m
0
WEST
RANGE
LOWER
PILOT
WEST
RANGE
CRYSTAL PASS
50 Km
UTAH (PAGE-12)


NEVADA
UTAH
X
UPPER PILOT
(MISS.)
LEATHAM
CHAINMAN
JOANA
LOWER
POSSIBLE
SOURCE BEDS
BASE OF LOWER crepida ZONE
DEVILS
GATE
PILOT
Calvinaria LS
GUILMETTE
320X
25 Km
0

SLIDE 6