Stratigraphic and Structural Analysis of the Phosphoria Formation, Southeast Idaho

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PRECISION GEOSOLUTIONS

Abstract

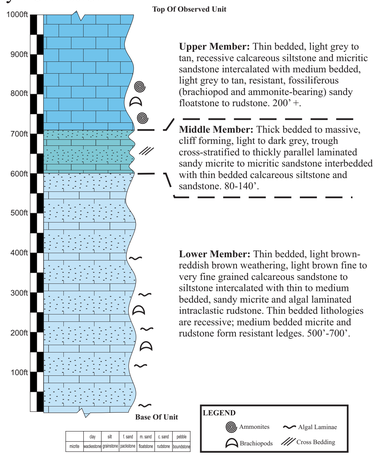
The Permian Phosphoria Formation in SE Idaho is the primary source of phosphate in North America. Phosphate is a primarily used in fertilizers, but can also be found in various foods and beverages, which makes phosphate a vital commodity. Documentation of the stratigraphic character and structural deformation of the Phoshporia Formation is required in order to evaluate the economic potential of the unit. Geologic mapping of the Phosphoria Formation in southeast Idaho has defined a north-plunging, nearly isoclinal anticline with a strike distance of nearly 15km in the hanging wall of the Meade Thrust. This anticline involves three geologic formations, including the Pennsylvanian-Permian Wells Formation, Permian Phosphoria Formation, and the Triassic Dinwoody Formation. Structural analysis indicates the the Phosphoria Formation has been dramatically thickened and thinned by flexural slip during deformation.

Introduction

Phosphate is produced from thin stratigraphic intervals within the Permian Phosphoria Formation. Accurate geologic mapping is critical for maximizing mine efficiency and minimizing environmental impact. Responsible mining requires development of high-resolution three dimensional models of the stratigraphic distribution and structural orientation of prospective zones within the Phosphoria Formation. Detailed geologic mapping of the Freeman Ridge area provides critical constraints on the three-dimensional geometry of the Phosphoria Formation.

Stratigraphic Analysis

Dinwoody Formation



Upper Member: Thin bedded, light grey to tan, recessive calcareous siltstone and micritic sandstone intercalated with medium bedded, light grey to tan, resistant, fossiliferous (brachiopod and ammonite-bearing) sandy floatstone to rudstone. 200' +.

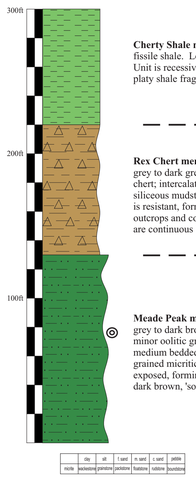
Middle Member: Thick bedded to massive, cliff forming, light to dark grey, trough cross-stratified to thickly parallel laminated sandy micrite to micritic sandstone interbedded with thin bedded calcareous siltstone and sandstone. 80-140'.

Lower Member: Thin bedded, light brown-reddish brown weathering, light brown fine to very fine grained calcareous sandstone to siltstone intercalated with thin to medium bedded, sandy micrite and algal laminated intraclastic rudstone. Thin bedded lithologies are recessive; medium bedded micrite and rudstone form resistant ledges. 500'-700'.

Thin to medium bedded ammonite-bearing rudstone marker bed of the upper Dinwoody Formation.

Medium bedded algal intraclastic rudstone characteristic of the lower member of the Dinwoody Formation.

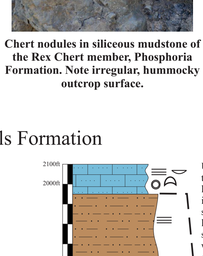
Phosphoria Formation



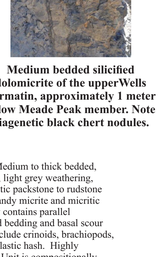
Cherty Shale member: Thin bedded, dark grey, fissile shale. Locally calcareous, micaceous in part. Unit is recessive; forms regolith containing angular, platy shale fragments. 50'-120'.

Rex Chert member: Thin to medium bedded, blue grey to dark grey, locally light grey, well bedded chert; intercalated with medium bedded nodular siliceous mudstone. Locally highly fractured. Unit is resistant, forming topographically prominent outcrops and conspicuous near-vertical 'flatirons' that are continuous for 100's meters along strike. 40'-140'.

Meade Peak member: Thin to medium bedded, dark grey to dark brown phosphatic shale, siltstone and minor oolitic grainstone; intercalated with thin to medium bedded, light brown weathering, very fine grained micritic sandstone. Unit is very poorly exposed, forming recessive shales, characterized by dark brown, 'sooty' (organic rich) regolith. 80'-180'.

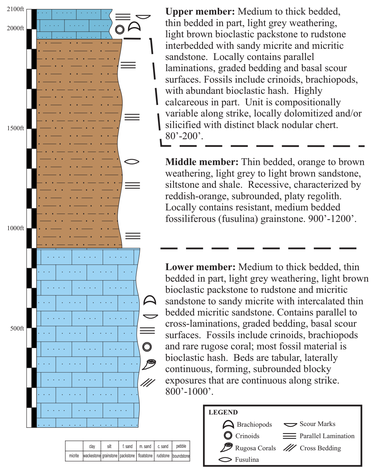


Chert nodules in siliceous mudstone of the Rex Chert member, Phosphoria Formation. Note irregular, hummocky outcrop surface.



Medium bedded silicified dolomicrite of the upperWells Formatin, approximately 1 meter below Meade Peak member. Note diagenetic black chert nodules.

Wells Formation



Upper member: Medium to thick bedded, thin bedded in part, light grey weathering, light brown bioclastic packstone to rudstone interbedded with sandy micrite and micritic sandstone. Locally contains parallel laminations, graded bedding and basal scour surfaces. Fossils include crinoids, brachiopods, with abundant bioclastic hash. Highly calcareous in part. Unit is compositionally variable along strike, locally dolomitized and/or silicified with distinct black nodular chert. 80'-200'.

Middle member: Thin bedded, orange to brown weathering, light grey to light brown sandstone, siltstone and shale. Recessive, characterized by reddish-orange, subrounded, platy regolith. Locally contains resistant, medium bedded fossiliferous (fusulina) grainstone. 900'-1200'.

Lower member: Medium to thick bedded, thin bedded in part, light grey weathering, light brown bioclastic packstone to rudstone and micritic sandstone to sandy micrite with intercalated thin bedded micritic sandstone. Contains parallel to cross-laminations, graded bedding, basal scour surfaces. Fossils include crinoids, brachiopods and rare rugose coral; most fossil material is bioclastic hash. Beds are tabular, laterally continuous, forming, subrounded blocky exposures that are continuous along strike. 800'-1000'.

Highly calcareous fossiliferous (crinoids, brachiopods) rudstone of the upper memberof the Wells Formation. Note feeding traces along ripple trough.

Medium to thick bedded, tabular, laterally continuous bioclastic floatstone and intercalated sandy micrite of the Wells Formation. Fossils include crinoids, rare rugosan corals, and abundant bioclastic hash.

DESCRIPTION OF MAP UNITS

Cenozoic

Qal **Quaternary Alluvium**:
Unconsolidated gravel, sand, silt and clay found in modern fluvial drainages and associated wetland deposits. Unconformably overlies Pennsylvanian to Triassic sedimentary rocks, and is preferentially located along the Permian Phosphoria/Triassic Dinwoody contact along north-trending drainages.

Qaf **Quaternary Alluvial Fan**
Unconsolidated boulders, cobbles, gravel, sand and silt forming an eastward-thinning wedge with an apex near the mouth of Stewart Canyon. Deposit thins from >100 feet near the mouth of the canyon to a feather edge in the Diamond Creek drainage.

Mesozoic

Triassic Sedimentary Rocks

Trd **Dinwoody Formation:**
Subdivided into three members within field area. Unit is lithologically heterogeneous. Unit is >2000' thick; map description encompasses basal 1000-1200'. Members include, in stratigraphic order:

Upper member:
Thin bedded, light grey to tan, recessive calcareous siltstone and micritic sandstone intercalated with medium bedded, light grey to tan, resistant, fossiliferous (brachiopod and ammonite-bearing) sandy floatstone to rudstone. (t=200+)

Middle member:
Thick bedded to massive, cliff forming, light to dark grey, trough cross-stratified to thickly parallel laminated sandy micrite to micritic sandstone interbedded with thin bedded calcareous siltstone and sandstone. (t=80-140').

Lower member:
Thin bedded, light brown-reddish brown weathering, light brown fine to very fine grained calcareous sandstone to siltstone intercalated with thin to medium bedded, sandy micrite and algal laminated intraclastic rudstone. Thin bedded lithologies are recessive; medium bedded micrite and rudstone form resistant ledges. (t=500-700')

Paleozoic

Permian Sedimentary Rocks

Pp **Phosphoria Formation**:
Subdivided into three members within field area; members not mapped individually due to poor exposure. Members include, in stratigraphic order:

Cherty Shale member:
Thin bedded, dark grey, fissile shale. Locally calcareous, micaceous in part. Unit is recessive; forms regolith containing angular, platy shale fragments. (t=50-120')

Rex Chert member:
Thin to medium bedded, blue grey to dark grey, locally light grey, well bedded chert; intercalated with medium bedded nodular siliceous mudstone. Locally highly fractured. Unit is resistant, forming topographically prominent outcrops and conspicuous near-vertical 'flatirons' that are continuous for 100's meters along strike. (t=40-140')

Meade Peak member:
Thin to medium bedded, dark grey to dark brown phosphatic shale, siltstone and minor oolitic grainstone; intercalated with thin to medium bedded, light brown weathering, very fine grained micritic sandstone. Unit is very poorly exposed, forming recessive shales, characterized by dark brown, 'sooty' (organic-rich) regolith.

Permian-Pennsylvanian Sedimentary Rocks

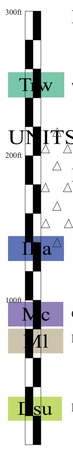
PIPw **Wells Formation:**
Subdivided into thee members within field area; members not mapped individually due to recessive nature of middle member and along-strike variability in nature and exposure of upper member. Members include, in stratigraphic order:

Upper member:
Medium to thick bedded, thin bedded in part, light grey weathering, light brown bioclastic packstone to rudstone interbedded with sandy micrite and micritic sandstone. Locally contains parallel lamina tions, graded bedding and basal scour surfaces. Fossils include crinoids, brachiopods, with abundant bioclastic hash. Highly calcareous in part. Unit is compositionally variable along strike, locally dolomitized and/or silicified with distinct black nodular chert. (t=80-200')

Middle member
Thin bedded, orange to brown weathering, light grey to light brown sandstone, siltstone and shale. Recessive, characterized by reddish-orange, subrounded, platy regolith. Locally contains resistant, medium bedded fossiliferous (fusulina) grainstone. (t=900-1200')

Lower member:
Medium to thick bedded, thin bedded in part, light grey weathering, light brown bioclastic packstone to rudstone and micritic sandstone to sandy micrite with intercalated thin bedded micritic sandstone. Contains parallel to cross-laminations, graded bedding, basal scour surfaces. Fossils include crinoids, brachiopods and rare rugose coral; most fossil material is bioclastic hash. Beds are tabular, laterally continuous, forming,

UNITS IMMEDIATELY ADJACENT TO FIELD AREA



Mesozoic

Triassic Sedimentary Rocks

TRw Woodside Shale

UNITS INFERRED TO BE IN THE SUBSURFACE

Paleozoic

Pennsylvanian Sedimentary Rocks

Pa Amsden Formation

Mississippian Sedimentary Rocks

Mc Chesterfield Formation

Ml Lodgepole Formation

Devonian Sedimentary Rocks

Dsu Devonian Sedimentary Undivided

MAP LEGEND

Map Symbols

- Bedding
- Bedding (tops known)

Contacts

- Known
- Approximate
- Inferred

Faults

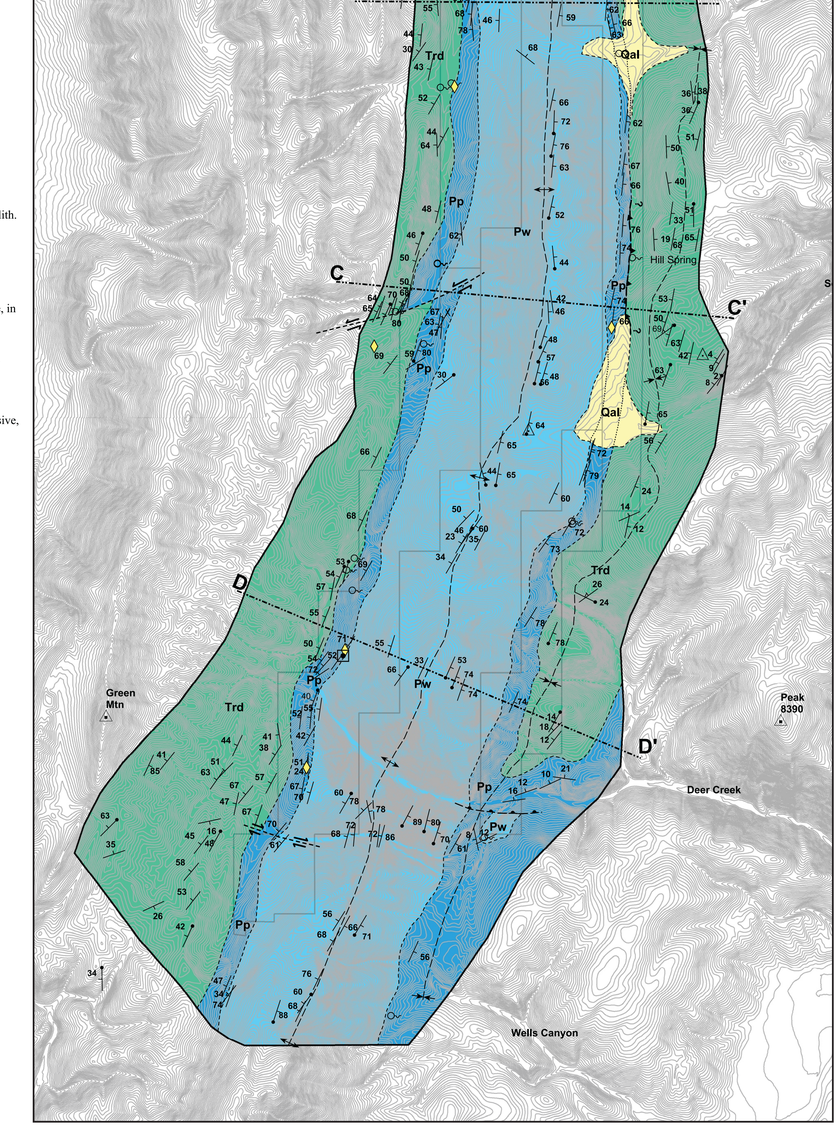
- Approximate Strike-Slip
- Inferred Strike-Slip
- Approximate Normal
- Inferred Thrust Fault

Folds

- Anticline
- Syncline

Features

- Drill Pad
- x Exploration Trench
- Survey Site
- Quarry
- Road Intersection
- Road
- Spring



N

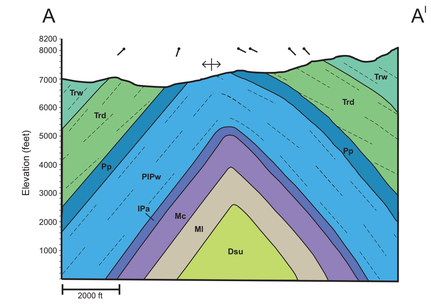
SCALE: 1:24,000

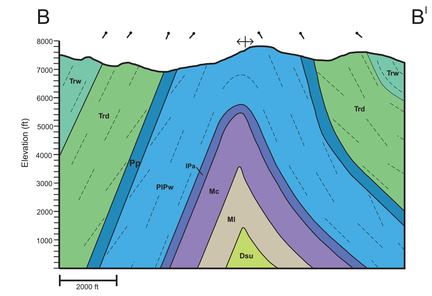
CONTOUR INTERVAL: 20 FEET

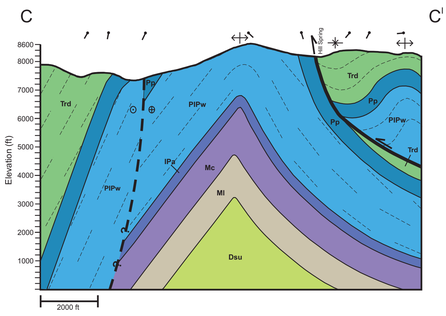
2 1 0 2 Kilometers

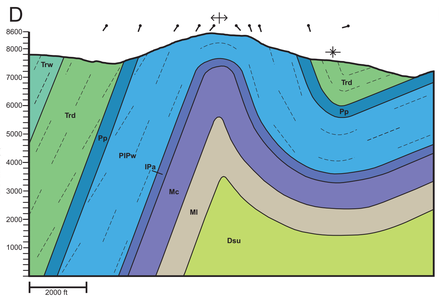
5,000 2,500 0 5,000 Feet

1 0.5 0 1 Miles





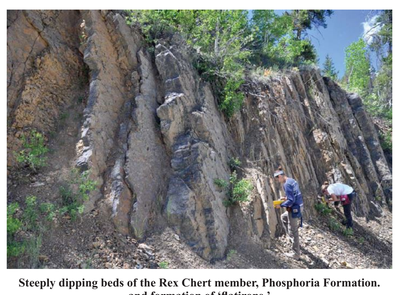




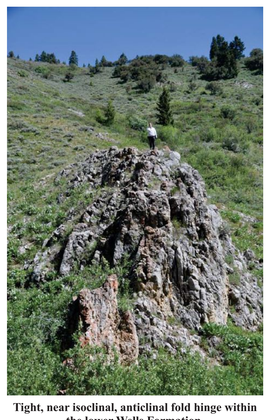
Structural Analysis

Regional Folding

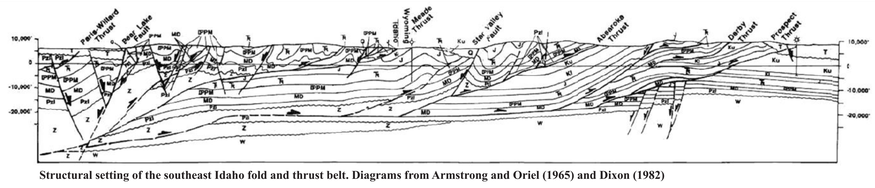
Our mapping area is located in the hanging wall of the Meade thrust in the Idaho-Wyoming thrust belt. The primary structure in the area is the Snowdrift Mountain anticline, which is a tight to near isoclinal, gently north-plunging anticline with a strike length of 8-9 miles (13-15 km). The fold is cored by the Pennsylvanian-Permian Wells Formation, whose lower member forms a resistant rib that outlines the trace of the anticlinal axis for the majority of its extent. The limbs of the anticline are steep, generally 60-75°, as evidenced by the consistent orientation of the Rex Chert member of the Phosphoria Formation.



Steeply dipping beds of the Rex Chert member, Phosphoria Formation. and formation of 'flatirons.'



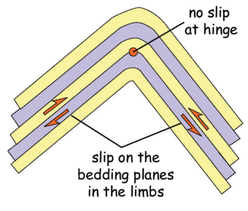
Tight, near isoclinal, anticlinal fold hinge within the lower Wells Formation.

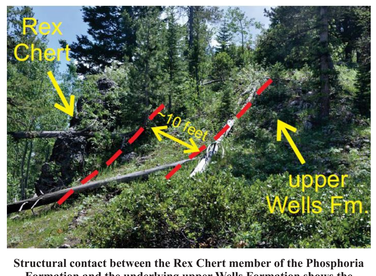


Structural setting of the southeast Idaho fold and thrust belt. Diagrams from Armstrong and Oriel (1965) and Dixon (1982)

Evidence of Flexural Slipping

The anticline is characterized by flexural slip folding, with bedding parallel slip evident along the steep limbs of the fold Flexural slip is suggested by structural discordance between the upper member of the Wells Formation and the overlying Rex Chert member of the Phosphoria, and between the Rex Chert and the overlying lower member of the Dinwoody Formation. Flexural slip is believed to have caused local structural thinning (and possible thickening?) of the Meade Peak member of the Phosphoria Formation.





Structural contact between the Rex Chert member of the Phosphoria Formation and the underlying upper Wells Formation shows the results. Note spatial proximity of the units across the contact, in which the Meade Peak member of the Phosphoria Formation is reduced to approximately 10 feet.

References:

Armstrong, F. C., and Oriel, S. S., 1965, Tectonic Development of Idaho-Wyoming Thrust Belt: American Association of Petroleum Geologists Bulletin, v. 49, p. 1847-1866

Dixon , J. S., 1982, Regional Structural Synthesis, Wyoming Salient of Western Overthrust Belt: The American Association of Petroleum Geologists Bulletin, v. 66, no. 10, p. 1560-1580.