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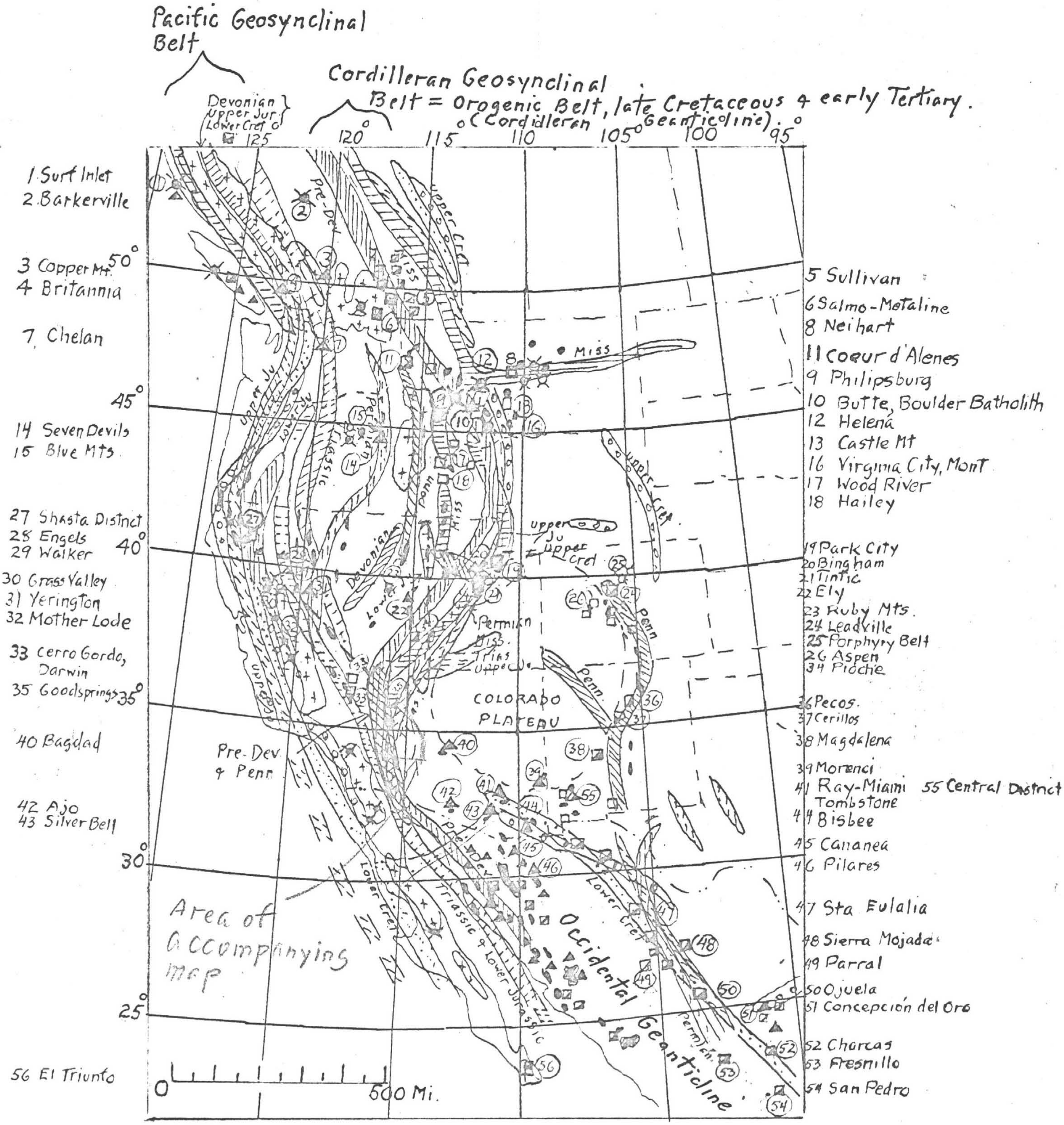
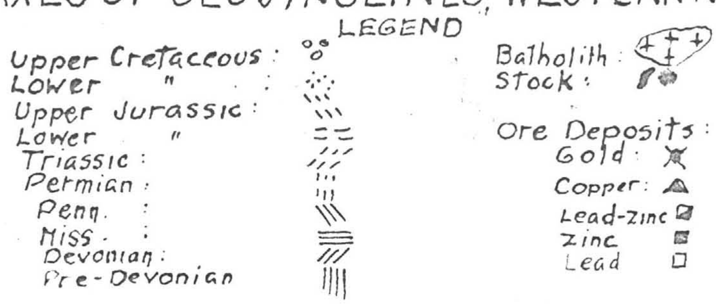
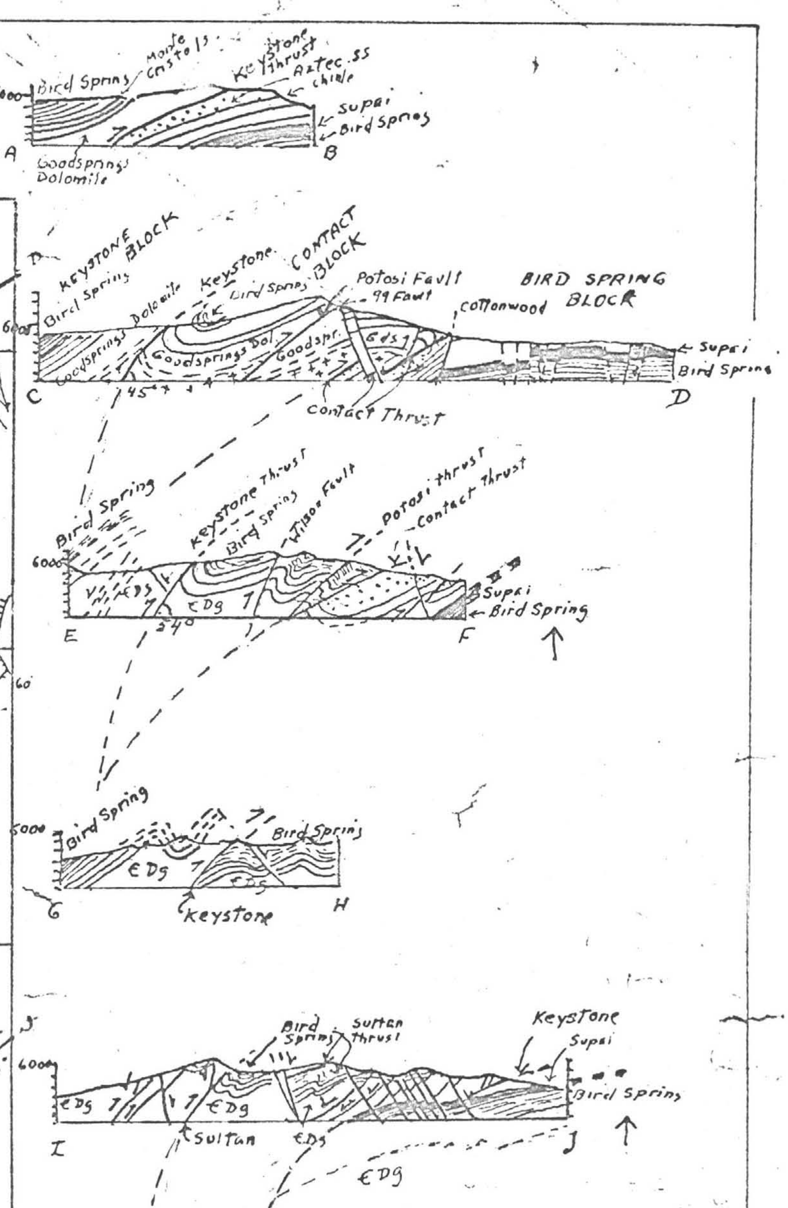
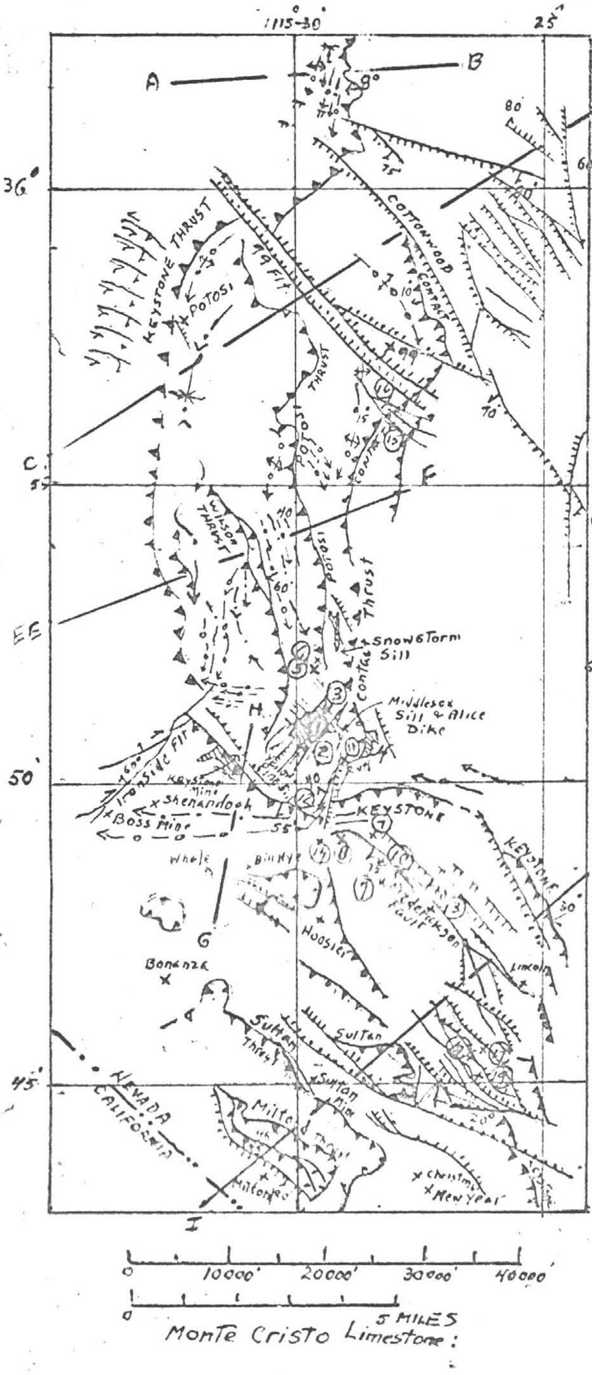


AXES OF GEOSYNCLINES, WESTERN NORTH AMERICA



E Wisser, Oct., 1955





Monte Cristo Limestone:

MINES. Numbers circled: ①

1. Yellow Pine Mine
2. Alice Mine
3. Prairie Flower Mine
4. Lavina Mine
5. Red Cloud Mine
6. Pilgrim Mine
7. Columbia "
8. Frederickson "
9. Lookout "
10. Argentina
11. Ruth
12. Belle
13. Mt. Top
14. Surprise
15. Contact
16. Pauline
17. Accident
18. Bullion
19. Anchor

GOODSPRINGS, NEVADA
STRUCTURAL MAP AND SECTIONS
After D.F. Hewett, USGS PP 162, 1931

LEGEND

Rock Formations (Sections)

- Aztec Sandstone :
- Supai :
- Bird Spring :
- Goodsprings Dolomite : €Dg
- Pre-Cambrian :

Granite Porphyry : (Plan)

Monte Cristo :

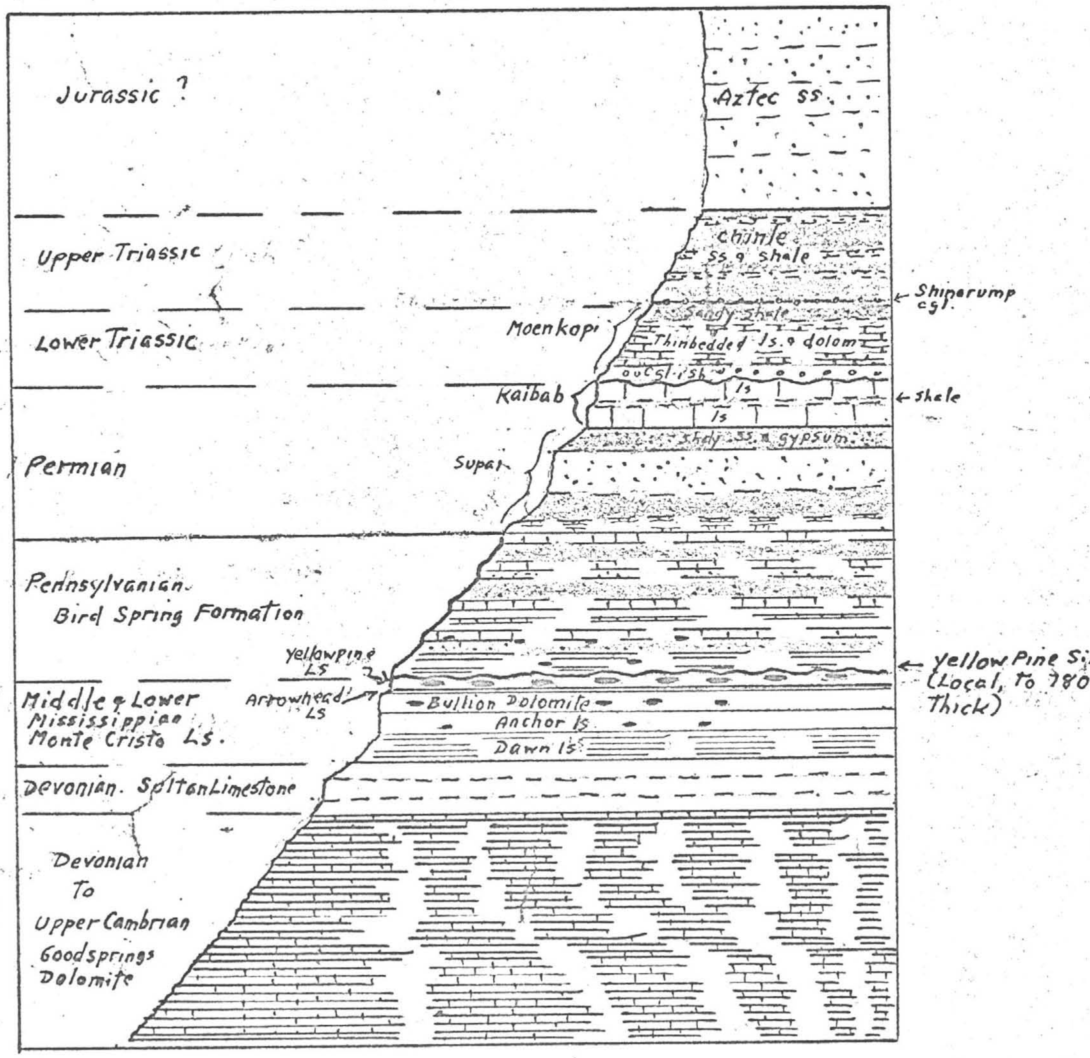
Faults

- Thrust, reverse faults
- Normal fault
- Horiz. displacement

Folds

- Anticline
- Syncline

E. Wisser 10/49



GOODSPRINGS, NEVADA
COLUMNAR SECTION, PRE-TERTIARY SEDIMENTS

0 1000' 2000' 3000'

LEGEND
Sandstone :
Shale :
Sandy Shale, Shaly sandstone :
Limestone, dolomite :
Lead-Zinc Ore Horizon :

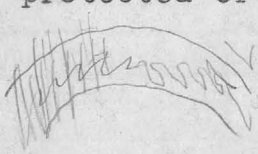
E. Wisser 10/49

MINING 111B.3B-1. Goodsprings,Nevada.

In examining the NE belt of mid-Cretaceous folding,what would we expect to see,in the light of what has been brought out? Obviously something like the situation pictured in the Spieker block diagrams. Fold overturned E,thrusts steepening to the west and with their upper plates shoved up and E.In miniature this is shown by position of Bingham,Ophir, Tintic in Diagram A.

In predicting what we should see,we must take into consideration not only the situation of the belt with respect to the geanticline (on its E margin)but also the nature of the rock section. Thick soft rock sections show extreme folding,flat thrusts; thick hard competent sections fold only on a simple scale,and break easily.

The majority rules here: where a thin competent bed lies in a thick soft section,it is carried along in the intricate folding but breaks to pieces in the process. Where a soft layer lies in a thick competent sectio it is apt to either be protected or sheared and folded a la Leith.



Goodsprings,Nevada.

Geology & Ore Deposits of the Goodsprings Quadrangle,Nevada. D.F.Hewett, USGS PP 162,1931.

See Section.13,000' (1240) strata,7000' ls.,largely competent. Goodsprings lies in Cordilleric trough ;pre-Devonian,esp.Cambrian very thick here.

Competence of beds in the Section is indicated by the way they weather

Thus Aztec ss competent,forms cliff.Massive,cross-bedded;ledge-maker, Moenkopi,sandy shale,tb ls,incompetent.Kaibab ls competent .Supai,massiv ss ledge,shaly ss above,below.

Bird Spring: Ls,dolomote in thin to thick beds separated by sh.,ss.

Unconfomity at base of Bird Spring IMP,standpoint of ore.

Detail Section, Monte Cristo Ls:

ORE	Yellow Pine ls(locallly altered to dolomote).Massive ledge,60-1'
	Arrowhead ls.Tb ls,alternating with shale.Incompetent 15'
Ore	Bullion dolomite.Massive. 185-300'

Ore- Anchor ls.Massive,locally dolomite 65-400
Dawn ls. Tb.Much is altered to dolomite 60-400

Sultan ls.

Generally rather tin-bedded ls and dol.

Goodsprings Dolomite

Thin-bedded light and dark gray dolomite.60' shale near top.

Note on bedding vs.competence: Seds,even apparently massive seds.,comm ly made up of thin laminae.If these stay welded together,massive,cliff-maker,competentRock is strong, resists stress,is brittle,tends to fracture rather than fold.

Other extreme:each lamina deforms as a unit,inter-lamina slipping. Shale has this habit.Limestone,sandstone (often poorly bedded or cross-bedded or thick-bedded-lack of laminae ipso facto)quartzite,laminas are welded.The more the shale intercalated layers,the more inter-lamina folding,the less competent the rock.Marble however may flow under heavy load,strong stress.

Under certain conditions shale not laminated.Does not fold intricately,flows, sets up conjugate shear planes.

In between are formations which weather as 1-5' beds

In the section,some 42% of beds competent.If these had been concentrated say at bottom,this unit would have reisisted folding,behave britt fractured.But competent beds scattered thru section.

Goodsprings a limestone replacement district,zinc-lead-silver.Note positionm in section of the OBs.They lie toward top of a competent hori 1500' thick (Sultan ls.upward),which lies between two major incompetent each over 2000' thick. That is the large-scale picture.

Small-scale picture: Within the competent layer there is a central incompetent horizon (Dawn ls) splitting the competent layer.

11/5/52 Dominant Goodsprings deformation was folding:thick cover of beds on flank of uplift. The thick layers of tb incompetent rks.folded,flowed readily;the relatively thin intercalated brittle layers,while they were forced to fold also,brecciated,shattered during the process. Those competent,also perhaps chemically favorable beds that lay lowest in the section, i.e. the first such beds to be met by ascending ore solutions, became loci for ore. While thrusting at Goodsprings c omplicates this picture, it is nevertheless a rule for ls.replacements.

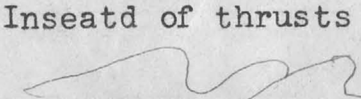
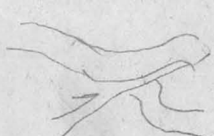
Hewitt, p.96:

"The outstanding physidal differences between the productive and unproductive parts of the stratigraphic section concern the character of the bedding. The 600 to 900' of beds that make up the Lower Miss. section (Yellowpine, Arrowhead, Bullion and Anchor) are distinctly more massive, homogeneous, and lacking in bedding planes than those above and below. Locally the Devomian beds become massive, but the overlying Penn. beds, as well as the underlying pre-Devonian beds, are uniformly thin bedded. The overlying beds also contain numerous thin layers of sandstone and shale. In many placesin the district it is apparent that the massive beds are competent and determine the general character of the folding (Willis definition), whereas the overlying thin beds are intricately folded to accomodate themselves to the simpler forms of the massive beds. It would therefore seem that the massive beds are more disposed to break and slip along the fractures than the overlying beds that would accomodate themselves to stress by folding and slipping along the bedding. However this may be, it is clear that the ~~lower Miss.~~ zone of lower Miss. beds is most favorable in the search for ore deposits."

<u>Intrusion:</u> Relatively sparse. Granite porphyry. Largest body is Yellow Pine sill, 780' thick S of YP mine. Next, irregular large dikes at Keystone, Lavina mines. Base of sill at YP lies some 30' above top of YP ls, the 30' being ss of Bird Spring.

<u>Structure</u>, <u>Tectonic</u> <u>History</u>: As shown on K^U map, Goodsprings lies in center of Eardley orogenoc belt, near E margin of Spieker belt of mid-K folding. Structural map.secfions show dominan feature strong folding, mainly N-S or roughly parallel with the orogenic belt, and esp. thrusting, thrusts

p.11 Nos parallel to folds. Instructive to compare these sections with those of Mansfield, Geogr., Geol., Min.Res.part of SE Idaho USGS PP 152, 1927, Bannock region. Folds really subordinate features to great thrusts. Inseatd of thrusts marking rupture of folds, folds may be due to thrusts.

11/2/51 Folding, thrusting along margin of rising mass. Mother Lode; Central Utah; Lewis thrust. Note steepepning of thrusts with depth: Big Horn. Bannock area, also fold, thrusts along margin of rising mass; there cover much thicker, much less competent. All these examples, folds overturned downslope, thrusts dip toward rising mass, upper plate shoved toward basin or lowland, thrusts steepen toward core of rising mass.

10/28/54 At Goodspring, doubtful if basin on SE of rising geanticline. Region land thr thruout K. Section at Goodsprings thick, 12,400'. But Hewett, Fig, 4, section comparing Inyo Range 65 mi. NW Goodsprings, Goodsprings, and Grand Canyon, 165 mi to E, shows rapid thinning of seds in trough to E. Goodsprings lies well E of thickest part of sed prism built up in Cordilleric trough in Paleo and by some later S Nevada troughs. There was therefore no trough, either an inert, fossil trough of old seds. or an active, sinking trough like central Utah, SE of Goodsprings during the deformation. Hence an adjacent trough not needed for such folding & thrusting. An adjacent land mass, rising, is needed.

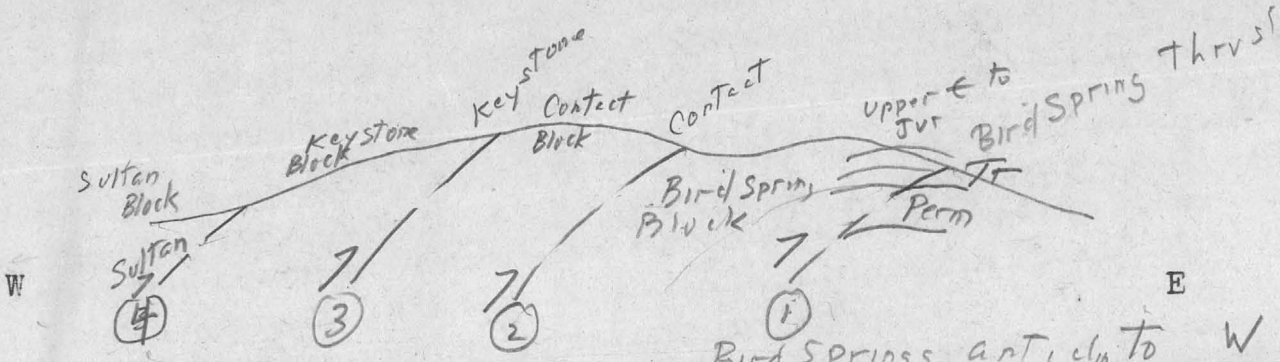
The Goodspring folds and thrusts are mere minor examples of the structures found along the belt of mid-K folding. The whole orogenic belt occupied by thrusts of attitude similar to that of Keystone in S Nevada. Some shown on lar large Tectonic Map. The thrust belt, 100 mi. wide, extends over 40 mi. NW of Goo Goodsprings Quad. (across width of belt). Belt at least 100 mi. long.

C.R. Longwell most familiar with this region: Mechanics of Orogeny. Am. Jnl. Sci., 243-A, Daly vol., 1945, 417-447. Shows thrusting, largely along bed planes on scale far larger than that at Goodsprings is rule. Most of thrusts strike roughly along trend of orgenic belt; they dip NW and steepen to NW.

Many of these thrusts have brought up Cambrian beds along their NW sides. Not pre-Cambrian because of great thickness of Paleo seds above it. Out in center of Cordilleric trough are 30,000' Paleo seds.

~~4~~

Four north-south thrust blocks at Goodsprings:



E one is oldest,thrusts get progressively younger ~~with depth~~.

1st Comparison with Clay Experkments. H.Cloos,Bonn. Most original references in German. Have translations. English accouts:

Outlines of Ø
Structural Geology,E.S.Hills,Nordeman Publ.Co.Inc.N.Y.1941:33-34;64-65;82;113-114,Plate 4;

Deformation of the Earth's Crust.W.H.Bucher,Princeton Univ.Press,1933. 144-146. Gives rough idea of philosophy of scale models.Mathematical exposition,also common sense version:

Theory of Scale Models as applied to the study of geologic structures. M.King Hubbert,GSA Bull.48,1937, 1459-1520.

In brief,theory as follows:Beeswax,clay used for century as non-brittle metarials to reproduce folding of ss,ls.,even qtzites. Why soft stuff to reproduce folding of competent material? Experiments to imittate successfully large-scale natural processes must reproduce dimensions of all factors involved on the reduced scale. Strength is a factor,as well as size. But different factors not in linear reference to each other;hence an empirical determination of their relative magnitudes in nature and in the model must precede experimentation aiming for quantitative accuracy. Scale models,hydraulic labs have done this for long time. Scale models of wave action-O'Brien.

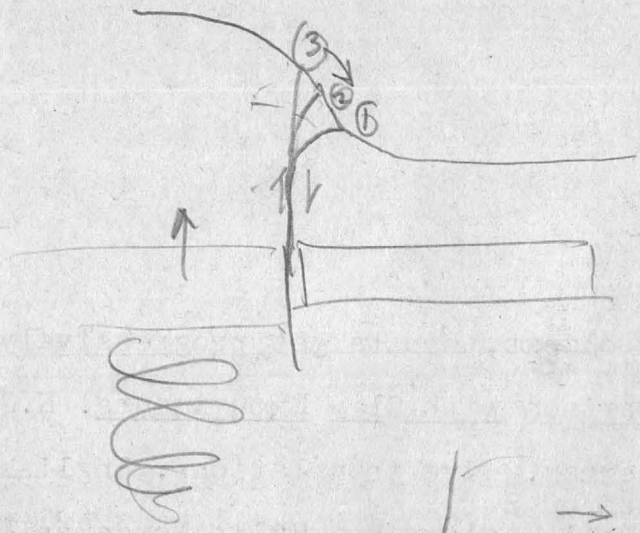
Difficult to get quatntitative accuracy in reproducing in experiment larger structural features of crust;at least a rough approach to a reduction of all factors to scale must be attempted.

Bigger the scale in nature,softer the model material. Rock folds,a few miles from crest to cret in nature,reproduced by beeswax and a mixture of wax and plaster of paris,folds measure a few cms.crest to crest,made in minutes instead of tens of tousands of years. When folded mt.systsm hundreds of kilometers wide are to be reproduced,still weaker stuff used, te reduce strength of earth's materials to scale. Cloos used paste of clay and water,molded to a cake,subjected to tension,compression,shear,uplift, sag.

Bucher, Fig.33,p.145.

4/2/54

Deformation plates will be referred to from time to time. See now Plate II,Sketch of Clay experiment adjoining Fig.B. Clay cake rested on adjoining metal plates;left-hand plate raised on screw to simulate



margin of uplift. Vertical fault was generated by the cu ting edgeof rising plate and shearing action against stationary plate. Fault worked up toward surface;as uplift rose.flow of material by gravity down flank rotated plane of thrust down hill. Actual movement on thrust had been nearly or quite completed before this rotation.Big Horn Mts. Thus the soft rock flowing moved the thrust surface;the thrust surface did not move the soft rock,after down-slope flow had started.

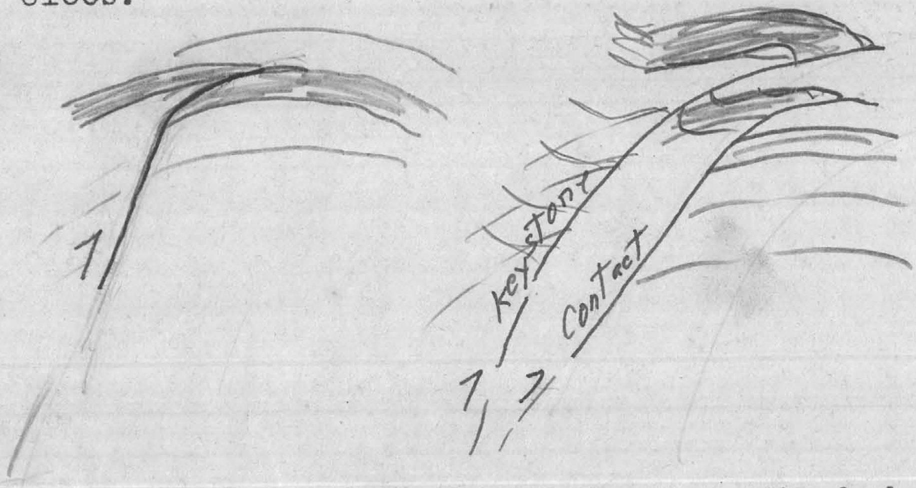
11/7/52

Note on your sections that the incompetent Goodsprings dolomite forms upper plates of thrusts.Such soft rock could not transmit compression as Lewis thrust shoved competent Beltian qtzite over soft Meso seds.

This is suggestive only. But note that Hewett's sequence,derived from independent field work, checks sequence of "thrusts" in clay exper-iment,where as each upper segment of the reverse fault turns over downslope,a new one shoots up to surface,to be turned over in its turn.

The experiment started with flat beds (marked on the flat clay cake) At Goodsprings,the beds were not flat at start of thrusting.The Bird Springs anticline had risen;a great reverse fault xxxx shoved up W flank of this anticline:

The fault surface was generated at depth:two fault blocks in the brittle crystalline basement correspond to the two metal plates of Cloos.

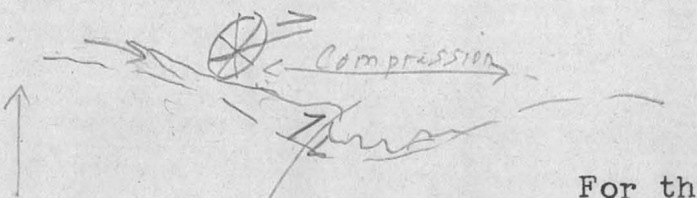


The fault surface first cut across the beds because it made a large angle with the beds.too large to turn and adapt itself to a surface of of least resistance,i.e. contact between 2 formations of dissimilar strength. But as fault climbed it started to overturn to E,got closer to paralleism with such a contact,finally followed it.

That these thrusts steepen with depth is not only shown on Hewett's sections;it is inescapable from mechanics of the thrusting. Section IJ: Goodsprings dolomite thrust over younger rocks parallel beding.In order to chop the upper segment of GS dolo.loose from the lower one,the Keystone fault must cross that formation, and rather quickly.not to have a displacement on the order of tens of miles. Hence Keystone must steepen about as shown.

More on thrust mechanics: 1st fault surface to be bent over to E found itself nearly parallel to W-dipping beds on W flank,Birds Springs anticlines.Thrust plane followed bedding;once it did,it had to flatten toward crest of arch. Since W wall of thrust still rising,this rise in part transformed into a thrust movement, But as attitude of beds flattened radically toward crest of arch,fault plane following these flat beds became progressively less and less adapated to further rise of W block. Since that block however continued to rise,another reverse fault,the Contact,shot up vertically from the basement. And so on for the Keystone, Sultan.

In conyrast with blocks below and aboge it, Contact block most highly folded. We are dealing with two uplifts,the old Bird Springs uplift and the new W uplift. Have hinted that folding prefers flanks of uplift;I believe it is because of flow of material down the slope. If so, flow into a trough results in compression



The flattening thrusts effect shortening down slope of uplift;folds do same thing.

For the limited area shown there is true lateral compression,since material is being crowded together in the valley.

After this thrust epoch came normal faulting.The Zn,Pb OBs were deposited just after or during formation of earliest of these. Thus after all folding and thrusting that is possible has been effected,deformation as in basement (where bedded rocks were in the main folded all they could be,perhaps in pre-Cambrian,hance basement behavior) by block faulting.

11/5/51

At Ruth mine,No.11,is a N-S normal fault,younger than Contact thrust, is premineral;galena shoot in Ruth mine lay in crushed beds adjacent to that flt. The dike of GP in which Lavina (4) veins occur was intruded along the Contact flt.p.45:"These relations indicate that the distribution of porphyry intrusions and ore deposits is controlled by the major thrust faults of the region".Since both magma and ore solutions came from depth,here again is a strong suggestion that thrusts steepen with depth.If they kept flat they could not have tapped deep-seated sources of magma and ore.

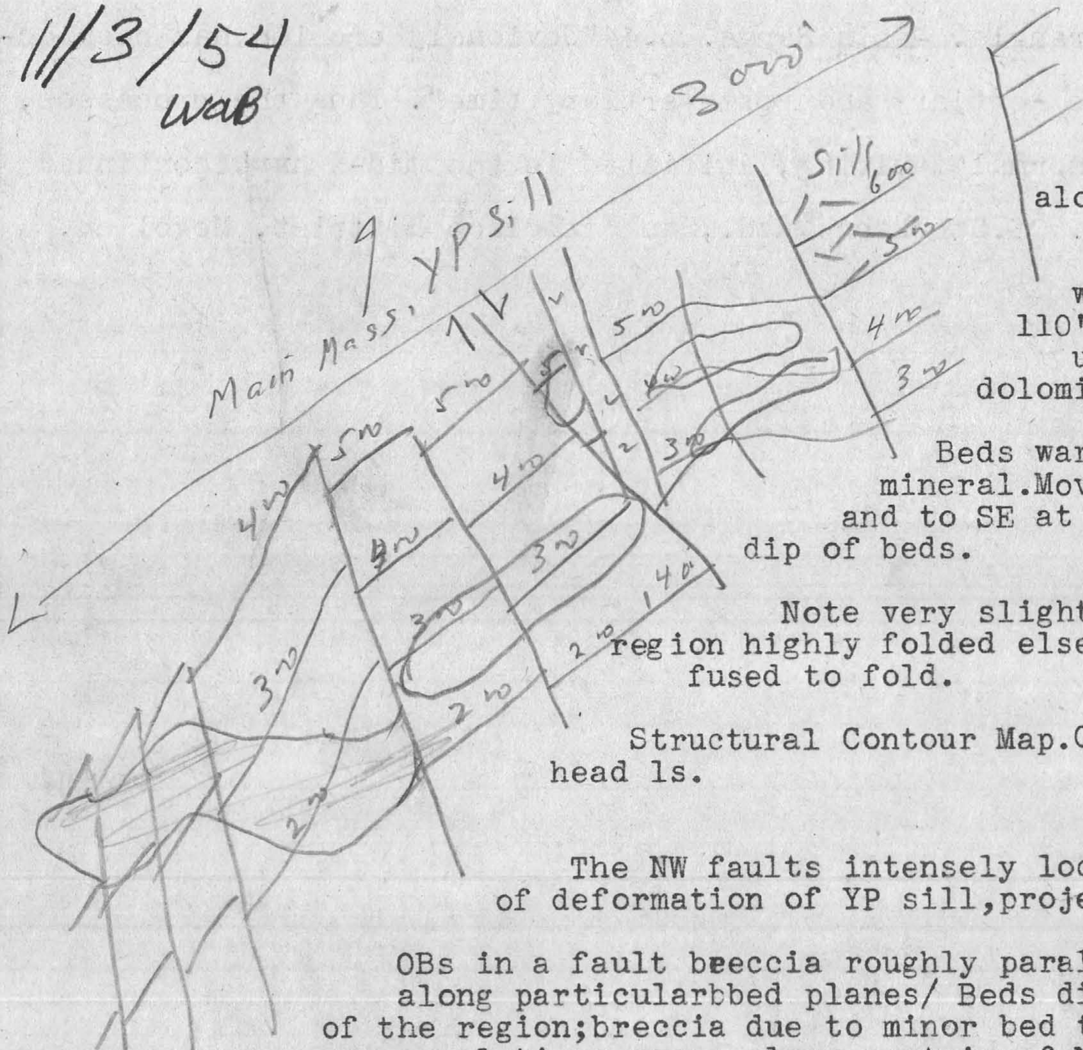
<u>Ore Deposits:</u> In dolomitized zones,mainly in YP (Yellow Pine) ls.,but also in Bullion dolomite,Anchor ls and a few at base of overlying Bird Spring. Mainly in open spaces,by filling,of dolomite breccia,remaining space filled with white dolomite and calcite.Replacement of dolom te breccia frags.confined to a few inches away from fractures.

Shape of OBs largely determined by shape of breccia zones.Majority of latter nearly parallel bedding.The zones underlie persistent walls whuch are minor thrusts. Some OBs along W-dipping normal faults.In general, steep portions of the thrusts,plus the normal faults were the ore channel Thrust breccias which stayed open owing to strength of a rubble and competence of the dolomite were favorable places for solutions that ascended along the steep faults to spread out to make tabular OBs.

<u>Yellow Pine Mine</u>: Chief producer. In HW of Contact thrust, close to Contact, and along S projestion of steeper Potosi thrust. Section E-F, farther N, shows narrow wedge between these thrusts. Lies in most complexly deformed area in district, the solar plexus or nucleus of deormation. Note curving of Keystone thrust to E S of YP. The thick YP sill added to heterogeneity of rocks being deformed. Minor ~~thrusts run along nearly al, major bed planes~~ thrust movement along bedding, to be described might represent dissipation of Potosi thrusting to S.

IMP. principle: Free fault movement, no strain. Hindered tendency to movement, severe strain, disruption, ore..

11/3/54 WAB



YP sill above, intruded along unconformity at base of Bird Spring. Arrowhead 10', dol. ls beds altenating with shale laminae. Yp ls, ore, 110', S part, 71', N. owing to unconformity. Light gray, xx, dolomitized.

Beds warped. Most of X-flts pre-mineral. Movement on most, NE side up n and to SE at angle slightly less than dip of beds.

Note very slight warping of beds in a region highly folded elsewhere. Thick YP sill refused to fold.

Structural Contour Map. Contours on top of Arrowhead ls.

The NW faults intensely localized here might be method of deformation of YP sill, projected into underlying beds.

OBs in a fault breccia roughly parallel to the beds rather than along particularbbed planes/ Beds dip NW, parallel to thrusts of the region; breccia due to minor bed thrusting. Hewett thinks ore solutions arose alomg certain of NW faults, spreading out into breccia zone. Ultimate channel probably Contact flt.

Looking at district as a whole, N of E-W segment, Keystone thrust, mines confined to Contact block. In detailmost of the mines hug the Contact and Potosi thrusts, and lie not far in the HW of these.

S of E-W segment of Keystone, triangle between Keystone and Ironside flts seems to have localized ore (Shanandoah Mine). Akso Frederickson

INSERT: Later History of Goodsprings.

After normal faulting and deposition of ore, came a period of great erosion, signifying active uplift; then other normal faults, further erosion meaning more uplift. Then vulcanism, rhy, latite andesite intrusions, tuffs, flows. Miocene. Still farther normal faults, on bigger scale, mainly outside the quadrangle. Basin Range. p.44 "Obviously erosion has been active through late Tertiary and post-Tertiary time". Thus the processes, erosion, upllft, normal faulting, initiated in the mid-K have continued into Pleistocene. Cf. Stockton Quzd., San Francisco District, Mogollon, Comstock.

fault;area of normal flts near SE corner. Sultan,Milford thrusts have localized some ore.

INSERT ←

Summary: Relatively thick, rather incompetent section,but not too far above basement.Section C-D.Major ore channels thrusts,which since exposed horizon not too far above basement,have not turned over very far.Favorable rocks are massive ls.,dolo.,brittle,inteecalated with softer layers.Subsidiary thrusting/not far in HW of major thrusts brecciated these massive horizons,also steep transgessive faults did likewise.

Main OB where massive sill impeded normal deformation of seds. The YP sill might also,of course,have acted as the so-called trap for ascending solutions. Leadville.

11/10/52

Exploration at Goodsprings: Where would you hunt for further ore. Can't say without detail,long study.But here is one pointer: Blue on map shows exposures of Monte Cristo ls. May be hidden OBs where this lies below surface.Favorable area,perhaps,Contact block,uncolored area S of Potosi mine-Sections C-D,E-F.Others in S. Leakage ore: poor showings in Bird Spring might be slight amount of ore that had leaked upward from better mineralization in YP ls at depth.Pick area showing strong deformation and espcially heterogenity of rock,with some smells of mineralization,as close as possible to a major thrust for a channel.Perhaps Wilson fault,Sec.#E-F.

An ore showing must be judged in relation to the favorability of the rock in which it appears.

November 1959

Geology and Mineral Deposits of the Goodsprings Area Neveada

I Location

South end of the Spring Mts., a range in southern Nevada adjacent to California boarder, ca. 25 mi. SW of Las Vegas

II Section

Age	Formation	Thickness
Quaternary	Alluvium	
Pliestocene	Gravels	125'
Tertiary	Tuff, breccia, flows of andesite, latite, rhyolite and basalt	0 - 200'
Jurassic	Aztec sandstone: massive red ss.	2100'
U. Triassic	Chinle fm.: Red shly. ss.	1000'
U. Triassic	Shinarump cgl.: ls. & chert cgl.	10 - 30'
L. Triassic	Moenkopi fm.: red & green sdy, sh. some thin bedded ls. and cgl.	750 - 950'
	UNCONFORMITY	
Permian	Kaibab ls.: Massive grey limestone	410 - 555'
	Supai fm.: Red ss., red & green shly. ss., minor gypsum beds	1000 - 1100'
Pennsylvanian	Bird Springs fm.: Gray ls. & dol. thin to thick bedded **	2500'
	UNCONFORMITY	
Mississippian	Monte Cristo ls.	
	Yellowpine ls. *	60 - 120'
	Arrowhead ls.	10 - 20'
	Bullion dol. ₸	185 - 300'
	Anchor ls. ▽	65 - 400'
	Dawn ls	60 - 400'
Devonian	Crystal Pass ls.	150 - 260'
	Valentine ls.	75 - 380'
	Ironside dol.	5 - 125'
Devonian to U. Cambrian	Goodsprings dol.	24500'
M. Cambrian	Bright Angel shale	240'
	Taperts sandstone	130'
	Unconformity	
Algonkian	Cgl., qtzite, dol.	
	UNCONFORMITY	
Archean	reddish granite gneiss	

III Intrusive Rocks

Igneous rocks, both extrusive and intrusive are of minor areal extent in Goodsprings Area. Igneous rocks can be divided thusly:

Early group: Granite porphyry dikes and sills; lamprophyre dikes. Pre-mineral and prob. E. Tertiary

Later group: Volcanic rks., extrusive andintrusive andesites, latites, rhyolites, basalts and Tuff. Post-mineral.

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* 35% of Known ore bodies occur along this horizon.

** 30% of known orebodies occur along this horizon.

▽ 15% of known ore bodies occur along this horizon.

₸ 20% of known ore bodies occur along this horizon.

IV Summary fo Structurel Events

Post-Jurassic to pre-Miocene
Folding
Overthrusting: Low angle overthrusts and their associated high angle thrust faults. Thrusting was from west to east.
Late Cretaceous to early Tertiary
Intrusion
Early normal faults (some follow steep reverse faults).
Mineralization.
Miocene to Pliocene
Late normal faults
Volcanic flows and tuffs.
Normal faults.

Complex faulting and thrusting prepared the country rock as receptors and carriers of ore fluids.

V Ore Deposits
Galena and sphalerite are major primary minerals. Chalcopyrite is a minor primary mineral.

VI Geologic Control of Ore Deposits
1. Lead-zinc or bodies occur along Fredrickson Fault
Copper ore bodies occur along Ironsides Fault.
2. Localization of ore bodies along the Monte Cristo ls. where massive beds of ls. and dol. have been broken and brecciated and are favorable loci of ore deposition.
3. Individual ore bodies are located within the Monte Cristo ls. where one or more of the follwing factors have rendered the ground permeable and hence favorable:
   a. Permeability of favorable ground primary and due to openings between surfaces of bedding.
   b. Permeability of ground secondary and related to:
      i. Openings dissolved by ground water circulating during Monte Cristo - Bird Springs erosion interval.
      ii. Openings produced mechanically by breaking of roks due mainly to:
         (A) Shearing along bedding and minor thrusts; effects largely localized in relatively massive rock either
            (1) oOverlain by relatively thin-bedded rock.
            (2) Interbedded with relatively thin-bedded rock.
         (B) Faulting and jointing in and along flexures.
         (C) Rifting and tearing.

References:
Albritton, Jr., C. C. et al., Geologic controls of Lead and Zinc deposits in Geodsprings (Yellow Pine) District, Nevada: USGS Bull 1010, 1954

Hewatt, D.F. (1939), Geology and ore deposits of the Goodsprings Quadrangle, Nevada; USGS Prof. Paper 162.

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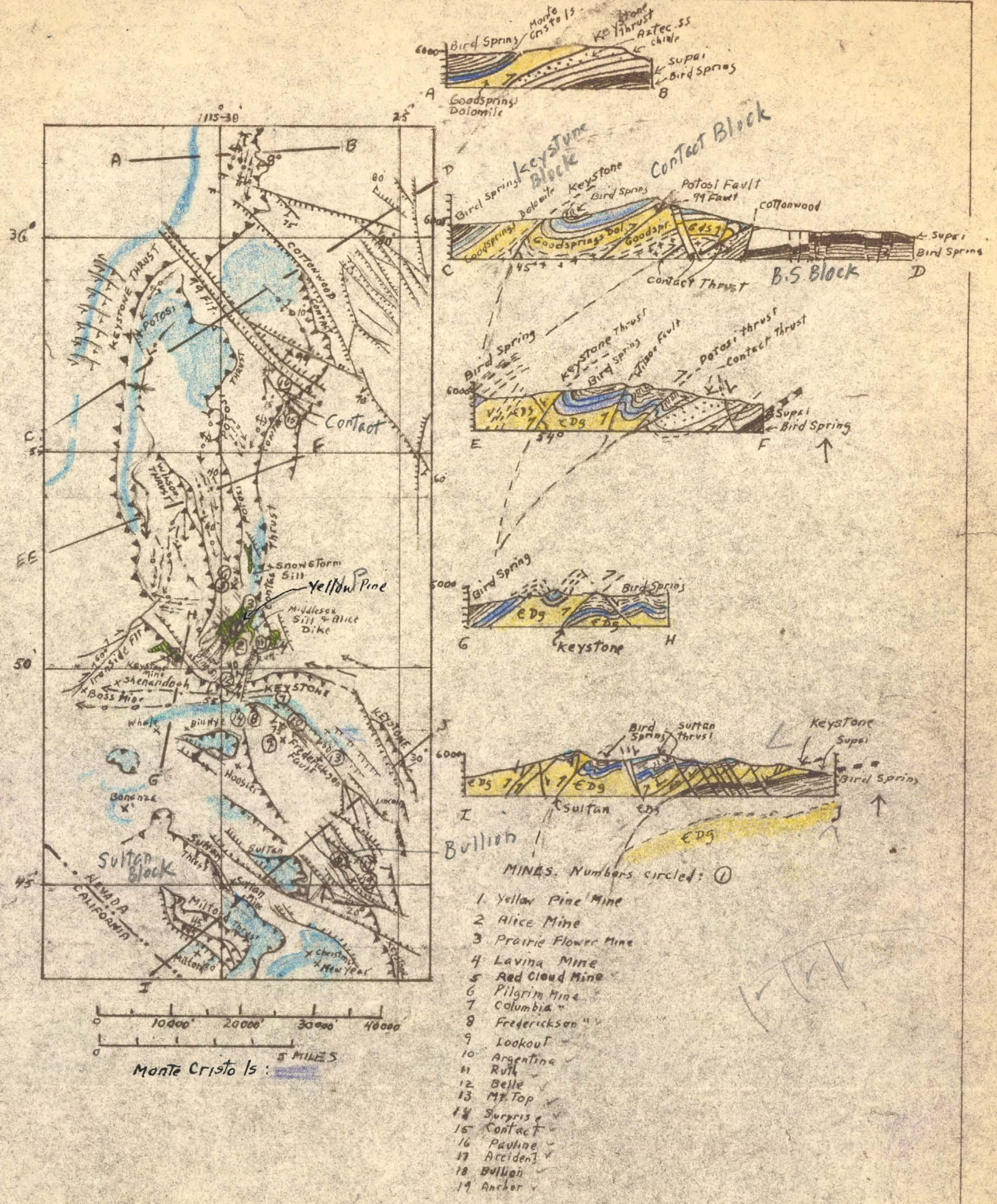

GOODSPRINGS, NEVADA
STRUCTURAL MAP AND SECTIONS
After D.F. Hewett, USGS PP 162, 1931

LEGEND

Rock Formations (Sections)
- Aztec Sandstone :
- Supai :
- Bird Spring :
- Goodsprings Dolomite : ЄDg
- Pre-Cambrian :

Granite Porphyry : (Plan)

Monte Cristo :

Faults
- Thrust, reverse faults
- Normal Fault
- Horiz. displacement

Folds
- Anticline
- Syncline

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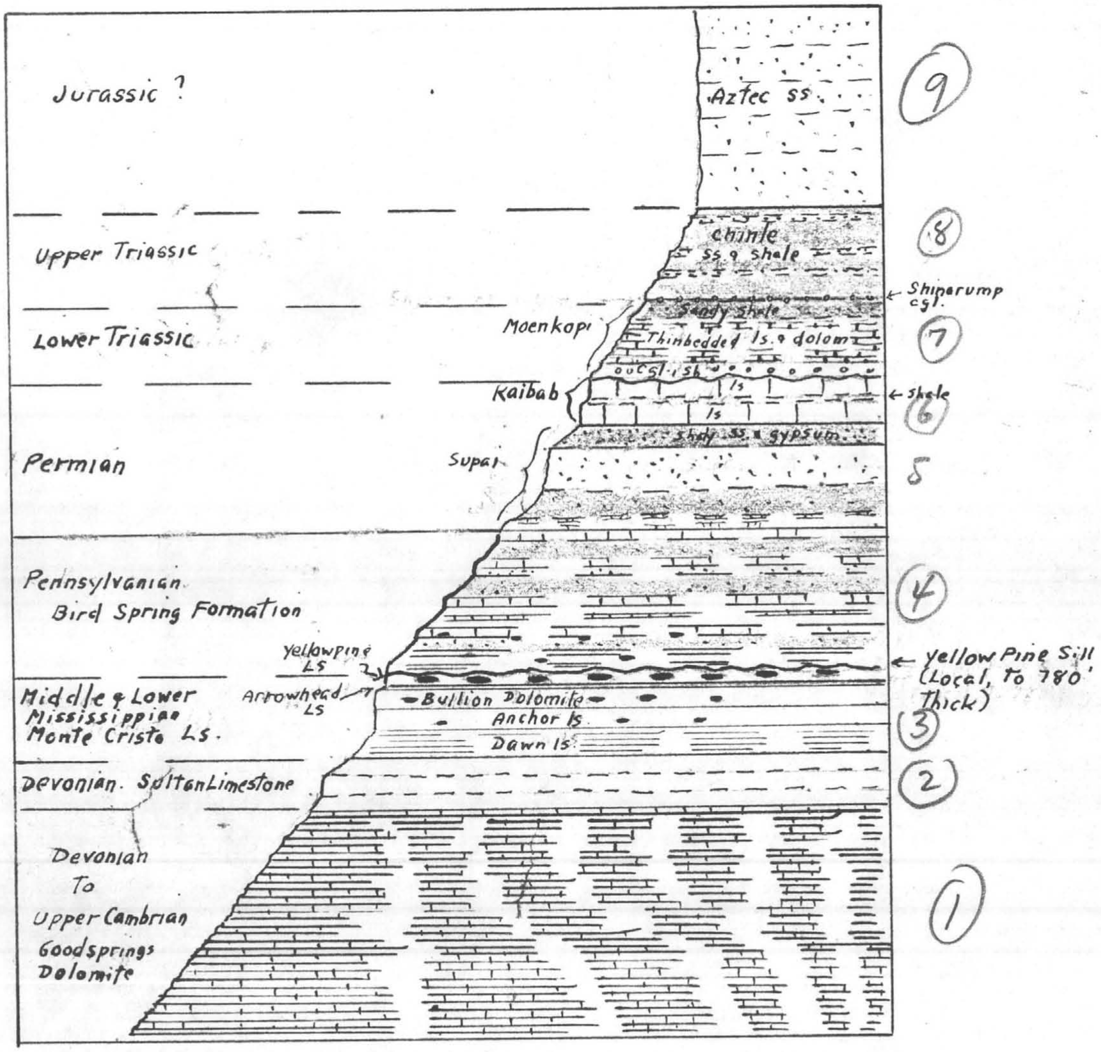

GOODSPRINGS, NEVADA
COLUMNAR SECTION, PRE-TERTIARY SEDIMENTS

0 1000' 2000' 3000'

LEGEND

Sandstone :
Shale :
Sandy Shale, Shaly sandstone :
Limestone, dolomite :
Lead-Zinc Ore Horizon :

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