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LINEAMENTS AND MINERAL OCCURRENCES IN PENNSYLVANIA*

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INTERDISCIPLINARY APPLICATION AND INTERPRETATION OF ERTS AND EREP DATA WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

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ABSTRACT

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W. S. Kowalik and D. P. Gold

A conservative lineament map of Pennsylvania interpreted from ERTS (LANDSAT)-1 channel 7 (infrared) imagery and SKYLAB photography has been compared with the distribution of known metallic mines and mineral occurrences. Of 383 known mineral occurrences, 116 show a geographical association to 1 km wide lineaments, another 24 lie at the intersection of two lineaments, and one lies at the intersection of three lineaments. The Perkiomen Cre k Lineament in the Triassic Basin is associated with 9 Cu-Fe occurrences. Six Pb-Zn occurrences are associated with the Tyrone - Mount Union lineament -- one on the lineament itself and five on lesser, adjacent lineaments. Thirteen other lineaments are associated with 3, 4, or 5 mineral occurrences each. Eleven mines with production exceeding $1,000,000 and 23 mines with production less than $1,000,000 lie on 1 km wide lineaments.

The lineament map and a table of mineral occurrences geographically associated with lineaments are presented. The information provided may be of value in exploration and will hopefully further field study of lineaments in the varied terranes of Pennsylvania.

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W. S. Kowalik and D. P. Gold

Office for Remote Sensing of Earth Resources, The Pennsylvania State University. Support for the work reported here was provided by NASA contract NAS 5-23133 as part of the ERTS-1 program and NASA contract NAS 9-13406 as part of the Skylab EREP program.

Lineaments are naturally occurring linear topographic and tonal features greater than 1 mile in length (Lattman, 1958). Lineaments, similar to shorter linear features known as fracture traces (Lattman and Nickelson, 1958; Lattman and Matzke, 1961; Kiem, 1962; Lattman and Parizek, 1964; Wobber, 1967; Siddiqui and Parizek, 1971, Parizek, 1975) appear to be surface manifestation of nearly vertical zones of fracturing or faulting in the underlying bedrock (Wier, et al., 1973; Gold et al., 1973; Gold et al., 1974). As fractured zones, lineaments may act as zones of increased permeability, channeling fluids in the crust. Smith, et al. (1971), Drahovzal (1973), and Krohn and Gold (1975), have cited possible genetic associations of lineaments and mineral occurrences in the Appalachians. Other workers have noted an association between increased density of lineament intersections and major mining districts in Nevada and Colorado (Levandowski, et al., 1973; Jensen, 1973; and Nicolais, 1973).

This paper reports those metallic mineral occurrences in Pennsylvania which lie near lineaments mapped from Landsat(ERTS)-1 satellite imagery (Kowalik and Gold, 1975) and verified from Skylab photography (Kowalik, 1975) where available. The lineaments were categorized by degree of expression and type of expression; the mineral occurrences were classified by host rock age, mineralization type, and value. The accompanying tables and figure document the mineral occurrences geographically associated with lineaments and serve as a base for a mineral exploration model.

The Lineament Map

The figure represents a conservative compilation of lineaments interpreted from the best Landsat-1 infrared (channel 7, 0.8-1.1μ) positive transparent images (Kowalik and Gold, 1975). Where available, Skylab S190B photography was used to verify these plots. During interpretation, each lineament was rated on two different ordinal scales, a scale of degree of definition and a scale of the nature of the expression. The most well defined lineaments were classified as 3, those of intermediate definition were classified as 2, and the least well defined were classified as 1. This classification of definition is represented on the figure by solid, dashed, and dotted lines, respectively. Class 3 lineaments are visually more reliable than class 1 lineaments and class 3 lineaments show less inter-operator variability. These lineaments are possibly younger or lie over zones of greater disturbance or dislocation at the surface than do class 1 lineaments. However, the degree of expression also appears to depend on artificial factors present during data collection, such as sun illumination azimuth and elevation angle, amount of foliage, and atmospheric conditions. The degree of expression is, therefore, a considerably less reliable criterion for defining relative disturbance at the surface than might otherwise be the case.

The second classification used on the figure describes each lineament as, A) alignments of major stream segments (streams in which water is visible on Landsat imagery); B) alignments of minor stream segments; or C) alignments of tonal features not classifiable as A or B. Although not precise, this classification provides the map user with an indication of the criteria used in mapping a particular lineament.

Procedure

The lineament map was interpreted on Landsat-1 channel 7 transparancies at the nominal image scale (1:989,000) using standard photogeologic techniques, after which the lineaments were digitized for computer processing. Two Fortran IV programs were written to sort the data by lineament length, degree of expression and type and to provide Calcomp plotter colored line maps at desired scales. The map was enlarged by means of the Calcomp plotter, to the scale of the Stream Map of Pennsylvania[1] (1:380,160) on which all known metallic mineral localities, mineral prospects, and abandoned and working mines had been plotted. During interpretation, few lineaments were drawn parallel to strike in order to avoid recording er sional differences between lithologies. Recognized cultural linear features were filtered out.

Most of the mineral occurrences were taken from the Mineral Atlas compiled by Rose (1970). These were updated with data from the Pennsylvania Geological Survey Open File Reports (1972 and No Date) and from theses by Hsu (1973) and Krohn (1975). The mineral classification scheme is based on host rock age after Rose (1970). (See Tables 1 through 3.)

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[1]Published in 1965 by the College of Agriculture, The Pennsylvania State University.

Typical widths and the subsurface nature of lineaments are poorly known or understood. Recent sampling by Krohn and Gold (1975) along the crest of Bald Eagle Mountain suggests that lineaments transecting the ridge are underlain by a disturbed zone with anamalous faulting, jointing, and brecciation averaging 1 km wide and ranging from 0.65 to 2 km in width. Assuming this applies to the valleys as well as to the quartzite ridge crest, and to the remainder of the State as well as to Bald Eagle Mountain, the 1 km wide zone is accepted here as a practical working width for the anomalous bedrock fracturing of a lineament. This width is used here in deciding whether a particular mineral occurrence is on or off a lineament.

Lineaments are approximated on the figure by straight lines and mineral occurrences are represented by points on the map. In reality, lineaments may vary in linearity (when viewed at larger scales), in width, in origin, and in the type and intensity of fracturing. Similarly, the shape of the mineral occurrences varies from their generalized form given here. Despite these approximations, this lineament - mineral occurrence comparison provides a first order measure of the association of mineralized areas with the lineaments mapped.

Tables 4 through 7 list, by host rock age, mineral occurrences lying on 1 km wide lineaments. Each table lists the lineament class and type, the type of mineralization, the county-number identification code devised by Rose (1970), the name of the occurrence, and the known value of the occurrence. Map users will require Rose's (1970) Plate I to locate individual mineral occurrences for comparison with the lineaments numbered on the figure here. Lineaments with associated mineralization are numbered on the figure according to their listing in Tables 4 through 7.

Discussion

The lists of metallic mineral occurrences coincident with lineaments do not necessarily imply they are genetically related, for the large numbers of lineaments and mineral occurrences makes chance associations inevitable. Of 383 known mineral occurrences, 116 show a geographical association with lineaments, and another 25 lie at intersections of two lineaments. We suggest that genetic relationships must be present, particularly where large numbers of mineral occurrences lie on a single lineament.

One possible factor relating mineral occurrences to lineaments is outcrop availability. Lineaments lying along major valleys which typically provide outcrop, especially on the Allegheny Plateau, probably bias the discovery of mineralization. Although many of the listed associations may be a result of such bias, it is not possible to identify them at this stage.

Two lineaments in Pennsylvania are notable here. The Tyrone - Mount Union lineament (Gold, et al., 1973; Krohn, 1975) in central Pennsylvania passes through three major water gaps along the Little Juniata River in crossing the Valley and Ridge Province from the southeast toward the Allegheny Plateau, where its trace coincides with a strike slip fault (Gray, et al., 1960). Previously mined Pb-Zn veins in Ordovician limestones lie on its trace at the town of Birmingham. Five Pb-Zn occurrences lie on lesser lineaments adjacent to the main lineament along the northwest trending zone described by Smith, et al. (1971). The Perkiomen Creek lineament trends north across the Triassic Basin in southeastern Pennsylvania. Nine Cu-Fe mineralized areas are distributed along its length. Sanders (1963) noted a period of late Triassic northeast and north trending fracturing accompanied by the main Triassic mineralization. The Perkiomen Creek lineament may be the surface expression of a major zone of Late Triassic fractures and may have controlled the locations of the mineralization at that time.

Conclusions

It is hoped that the tables and figure presented will provide users with clues to possible controls of metallic mineralization which will be of value in prospecting in Pennsylvania. The Tyrone - Mount Union lineament complex and the Perkiomen Creek lineament are the most strongly associated with mineralization in Pennsylvania. Other un-named lineaments listed in Tables 4 through 7 are geographically associated with 3, 4, and 5 mineral occurrences each. (See lineaments 1, 2, 10, 12, 15, 29, 47, 58, 60, 65, 83, 88, and 95.)

Further work with surface and subsurface structural expression of lineaments will be necessary to define and separate lineaments genetically, and to sort out those most likely to be mineralized. The present study will hopefully encourage further field study of lineaments in varied terranes across the State.

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Table 1: Key to Deposit Types*

Host Rocks	Type	Description
PreCambrian and Piedmont	A	Cr with minor Ni, Cu, and Fe, associated with ultramafic rocks.
	B	Ni and Cu sulfides with mafic to ultramafic rocks (Gap Nickel).
	C	Mo, Cu, U and other elements in pegmatites, or associated with pegmatites.
	D	Cu and other elements in gneiss, schist, metagabbro and related rock.
	E	Native Cu and Cu sulfides in metabasalt (Lake Superior Type).
Paleozoic	F	Appalachian-type Zn-Pb deposits in Cambro-Ordovician Ls.
	G	An-Pb sulfides in Helderberg-Tonoloway Limestones.
	H	Other Zn-Pb in sedimentary rocks.
	I	Barite in limestone.
	J	Zn-Pb-Cu sulfides as fracture fillings and veins in ls.
	K	Wurtzite and other sulfides in nodules.
	L	Sandstone-type Cu-U, U, and Cu deposits.
Triassic	M	Cu, Au, and other elements in Triassic diabase.
	N	Cornwall-type magnetite-Cu deposits.
	O	Cu in Triassic sediments adjacent to diabase, and related deposits.
	P	Cu in Triassic sediments distant from diabase.
	Q	Zn-Pb-Cu in quartz veins cutting Triassic and Precambrian rocks (Phoenixville Type).
	R	U in Triassic sediments.
Unclassified	S	Other Cu.
	T	Other Ni.
	U	Other Barite.
	W	Miscellaneous.

Table 2: Approximate Production of Deposit Types at 1968 Prices*

Type	Description	Value (dollars)
A	Chromite	5 million
B	Gap Nickel	7 million
E	Copper in metabasalt	10 thousand
F	Appalachian zinc	50 million
G	Silurian lead-zinc	110 thousand
L	Sandstone copper-uranium	10 thousand
N	Cornwall-type magnetite	1 billion
O	Copper adjacent to diabase	1 thousand
P	Copper in Triassic Red Beds	1 thousand
Q	Phoenixville Type	1 million

*From Rose (1970), Table 1.

Table 3: Symbols Used in Tables 4 through 7*

Symbol	Production Class
M	Mineral locality
P	Mineral prospect
L	Production less than 1 million dollars
H	Production greater than 1 million dollars

*From Rose (1970), Table 2.

Table 4: Precambrian and Piedmont Host Rock Mineral Occurrences Associated with Lineaments[a]

LINEAMENT Number	Class	Type	ASSOCIATED MINERALIZATION[b] Type	County Code[c]	Name	Production Class
1	2	B	I	Franklin 4	Near Waynesboro	M
			E	Adams 22*	Bingham (Cu Furnace) Mine	L
			E	Adams 23*	Red Hill Mine	L?
2	1	B	E	Adams 22*	Bingham (Cu Furnace) Mine	L
			E	Adams 23*	Reed Hill Mine	L?
			O	Adams 17	Fairfield South West	P
3	1	B	E	Adams 26*	Culp (Deshler) Shaft	P
			E	Adams 25*	Bechtel Shaft	P
4	3	B	E	Adams 25*	Bechtel Shaft	P
			E	Adams 26*	Culp (Deshler) Shaft	P
5	1	B	A	Lancaster 22	Newbold Mine	L
			A	Chester 33	Hillside Mine	L
6	3	B	A	Lancaster 20	Carter (Texas) Mine	L
			A	Lancaster 21	Wood Mine	H
7	1	C	D	Chester 9*	Keystone Quarry (Cornog)	M
8	2	B	C	Delaware 19*	Upland Station	M
9	1	B	C	Delaware 19*	Upland Station	M
10	1	B	C	Delaware 12	Franklin's Paper Mill	M
			C	Delaware 15	Leiper's Quarry	M
			C	Delaware 17	Deshong Quarry	M

(Continued)

[a] Lineaments with associated occurrences of different host rock ages are listed under the host rock.

[b] From Rose (1970) less noted otherwise. See Tables 1, 2 and 3 of this report.

[c] A single asterisk indicates location on the intersection of 2 lineaments. A double asterisk indicates location on the intersection of 3 lineaments. For localities with more than one mineral occurrence, not all of these may occur on one lineament — some may occur on one and others on another.

Table 4 (continued)

LINEAMENT			ASSOCIATED MINERALIZATION			Production
Number	Class	Type	Type	County Code	Name	Class
11	2	B	A	Delaware 3	Worrell	M
			A	Delaware 4	Blue Hill	M
12	1	C	D	Philadelphia 17	George's Hill	M
			Q	Philadelphia 18	Falls of Schuylkill	M
			C	Philadelphia 19	Pennsylvania Ave	M
13	3	A	D,I	Montgomery 37	Mogeetown	M
			D	Montgomery 39	Gladwyne	M
14	2	B	D	Montgomery 44	Paper Mills Station	M
15	3	C	W	Montgomery 41	Smith's Quarry	M
			C	Montgomery 42	Heacock's Quarry	M
			D	Montgomery 43	Ogontz	M
16	1	B	C	Berks 8	Pricetown	M
17	1	B	C	Northampton 5	Hellertown	M
18	1	B	E	Franklin 1	Hayes Creek	P
19	2	C	D	Chester 9*	Keystone Quarry (Cornog)	M
20	2	B	D	Philadelphia 1	Bells Mill Road and Wissahickon Valley	M

Table 5: Paleozoic Host Rock Mineral Occurrences Associated with Lineaments[a]

LINEAMENT			ASSOCIATED MINERALIZATION			Production
Number	Class	Type	Type	County Code	Name	Class
21	3	C	I	Franklin 5	Near Waynesboro	M
22	1	B	J	York 4	York Valley Line	M
23	1	C	F	Lancaster 10	Bamford Mine	H?
24	2	C	F	Lancaster 11	Herr's Mine	L?
			F	Lancaster 12	Flory's Mill Quarry	M
25	1	C	F	Lehigh 6	Friedensville	H
26	2	A	F	Lehigh 3	Allentown	P
27	3	A	H	Lehigh 1	Lehigh Gap	M
28	1	B	H	Monroe 1	Middle Smithfield Township	P
29	3	A	L	Carbon 2	Penn Haven Junction	P?
			L	Carbon 3	Penn Haven Junction	P
			L	Carbon 4	Butcher Hollow	P
30	2	B	L	Wyoming 1	Nicholson Township	M
31	2	C	L	Wyoming 2	Forkstown	P
32	1	C	L	Luzerne 3	Laurel School	M
33	2	B	L	Schuylkill 2	Hecla	M
34	1	C	H	Schuylkill 3*	Adamsdale	M

(Continued)

[a]See footnotes to Table 4.

Table 5 (continued)

LINEAMENT			ASSOCIATED MINERALIZATION			Production
Number	Class	Type	Type	County Code	Name	Class
35	2	B	H	Schuylkill 3*	Adamsdale	M
36	1	B	H	Schuylkill 1	Pottsville	M
37	1	A	G	Northumberland-1	Doughty Mine	L
38	3	B	L	Montour 1	Near Roaring Creek	P
39	1	B	L	Columbia 1	Grassmere Area (8 occurrences)	P
40	1	B	L	Columbia 1	Grassmere Area (8 occurrences)	P
41	1	B	L	Lycoming 3*	Beaver Lake (5 localities)	P
42	1	B	L	Lycoming 3*	Beaver Lake (5 localities)	P
43	1	B	L	Lycoming 3	Beaver Lake (5 localities)	P
			L	Lycoming 2	Hughesville (3 localities)	P
44	2	B	L	Sullivan 5	West of Beech Glen (4 localities)	P
45	3	B	L	Sullivan 3*	Dushore	P
46	2	B	L	Sullivan 3*	Dushore	P
47	2	B	L	Bradford 1*	Carpenter Mine	L
			L	Bradford 2*	Near New Albany	P
			L	Bradford 6*	Near New Albany	L
			L	Bradford 3*	Near New Albany	P
48	1	C	L	Bradford 5	Near New Albany	P
49	3	B	H	Sullivan 1	Millview	M

(Continued)

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Table 5 (continued)

LINEAMENT			ASSOCIATED MINERALIZATION			
Number	Class	Type	Type	County Code	Name	Production Class
50	3	C	L	Bedford 2	Near Breezewood	M
51	3	B	L	Huntingdon 4	Brownsville	P
52	3	B	L	Huntingdon 6	Mapleton (4 localities)	M
			H	Huntingdon 6	Mapleton Roadcut	P
53	2	A	F	Blair 1	Birmingham	L
54	2	B	G	Blair[b]	Knisley Quarry (NE Sproul)	M
55	2	B	H	Centre 1	Milesburg Gap	P
56	1	C	H	Armstrong 1	North Vandergrift	M
57	1	C	K	Allegheny 3*	Glassmere	M
			K	Allegheny 4*	Creighton	M
58	1	A	K	Allegheny 3*	Glassmere	M
			K	Allegheny 4*	Creighton	M
			K	Allegheny 2	Springdale	M
59	1	C	K	Allegheny 5	Witmer	M
60	3	B	K	Allegheny 1	Abers Creek	M
			K	Westmoreland 1	Un-named	M
			K	Westmoreland 2	Murraysville	M
61	1	C	L	Beaver 1	Darlington	M
62	1	C	K	Butler 1	Butler	M
63	1	B	H	Butler 2	West of Parker	M

(Continued)

[b]From the Pennsylvania Geological Survey Report.

Table 5 (continued)

LINEAMENT			ASSOCIATED MINERALIZATION			
Number	Class	Type	Type	County Code	Name	Production Class
64	3	B	L	B ford 8	Canton	P
65	2	B	L	Bradford 6*	Near New Albany	L
			L	Bradford 2*	Near New Albany	P
			L	Bradford 1*	Carpenter Mine	L
			L	Bradford 3*	Near New Albany	P
66	1	B	L	Lycoming 3*	Beaver Lake (5 localities)	P
67	1	B	L	Lycoming 3*	Beaver Lake (5 localities)	P
68	1	B	L	Lycoming 2	Hughesville (3 localities)	P
69	1	A	L	Union 3	Opposite Northumberland	P
70	2	B	L	Huntingdon 6	Mapleton (4 localities)	M
71	1	C	F	Lancaster 14	Lancaster	M
72	3	B	H	Pike 1	Westfall Township	M
73	3	B	U	Centre[c]	Near Coleville	M
74	1	C	U	Centre[c]	Lambs Gap	M
75	2	C	F	Blair	Near Arch Spring	M
76	2	B	F	Blair*	Near Waterstreet	M
77	2	B	F	Blair*	Near Waterstreet	M

[c]From Hsu, 1973

[d]from R. C. Smith, personal communication.

Table 6: Triassic Host Mineral Occurrences Associated with Lineaments[a]

LINEAMENT			ASSOCIATED MINERALIZATION[b]			
Number	Class	Type	Type	County Code[c]	Name	Production Class
78	2	C	N	Adams 13	Orrtana	M
			N	Adams 14	Carr Hill	P
79	3	C	O	Adams 2*	Teeter's Quarry	M
			O	Adams 3	Gettysburg	M
80	1	C	O	Adams 2*	Teeter's Quarry	M
81	2	C	P	Adams 1	Bonneaughtown	M
82	1	C	O	Adams 5	Near Heidlersburg	P
83	1	C	N	York 24	Bender and vicinity	L
			N	York 26	Dillsburg North	P
			N	York 25	Franklintown Area (4 localities)	P
84	1	C	N	York 25	Franklintown Area (4 localities)	P
			N	York 23*	Dillsburg (3 localities)	H
85	1	C	N	York 23*	Dillsburg (3 localities)	H
			N	York 21	Wellsville North East (2 localities)	P
86	1	C	P	York 6	LeCrons Copper Mine	P
87	2	C	N	Chester 7*	French Creek Mines	H
			N	Chester 8	Knauertown	P
88	2	C	N	Chester 7*	French Creek Mines	H
			N	Chester 6	Southeast of Hopeville	L?

(Continued)

[a] See footnotes to Table 4.

Table 6 (continued)

LINEAMENT			ASSOCIATED MINERALIZATION			Production
Number	Class	Type	Type	County Code	Name	Class
			Q	Chester 16	Wheatly, Phoenix, Brockdale, and Chester County Mines	L
			Q	Chester 17	Napoleon Mine	P
			Q	Chester 12	Morris Copper Mine	L?
89	2	B	Q	Montgomery 27*	Arcola	M
90	2	A	Q	Montgomery 27*	Arcola	M
			Q	Montgomery 28	Perkiomen Mine	L
			Q	Montgomery 29*	Ecton Mine	L
			Q	Montgomery 30	Wetherill Mine	L?
			P	Montgomery 25	Grater's Ford	M
			O	Montgomery 4	Kibblehouse Quarry	M
			P	Montgomery 26	Collegeville Station	M
			O	Montgomery 6	Hendricks Station	P
			O	Montgomery 21**	Schwencksville	P
91	2	A	O	Montgomery 21**	Schwencksville	P
			O	Montgomery 3	Young's Mine	L?
92	3	C	O	Montgomery 20	Old Perkiomen Mine	L
			O	Montgomery 21**	Schwencksville	P
93	1	B	Q	Montgomery 29*	Ecton Mine	L
94	1	B	N	Berks 3	Boyertown	H
95	3	A	O	Bucks 20	New Hope	M
			R	Bucks 19	Un-named	P

(Continued)

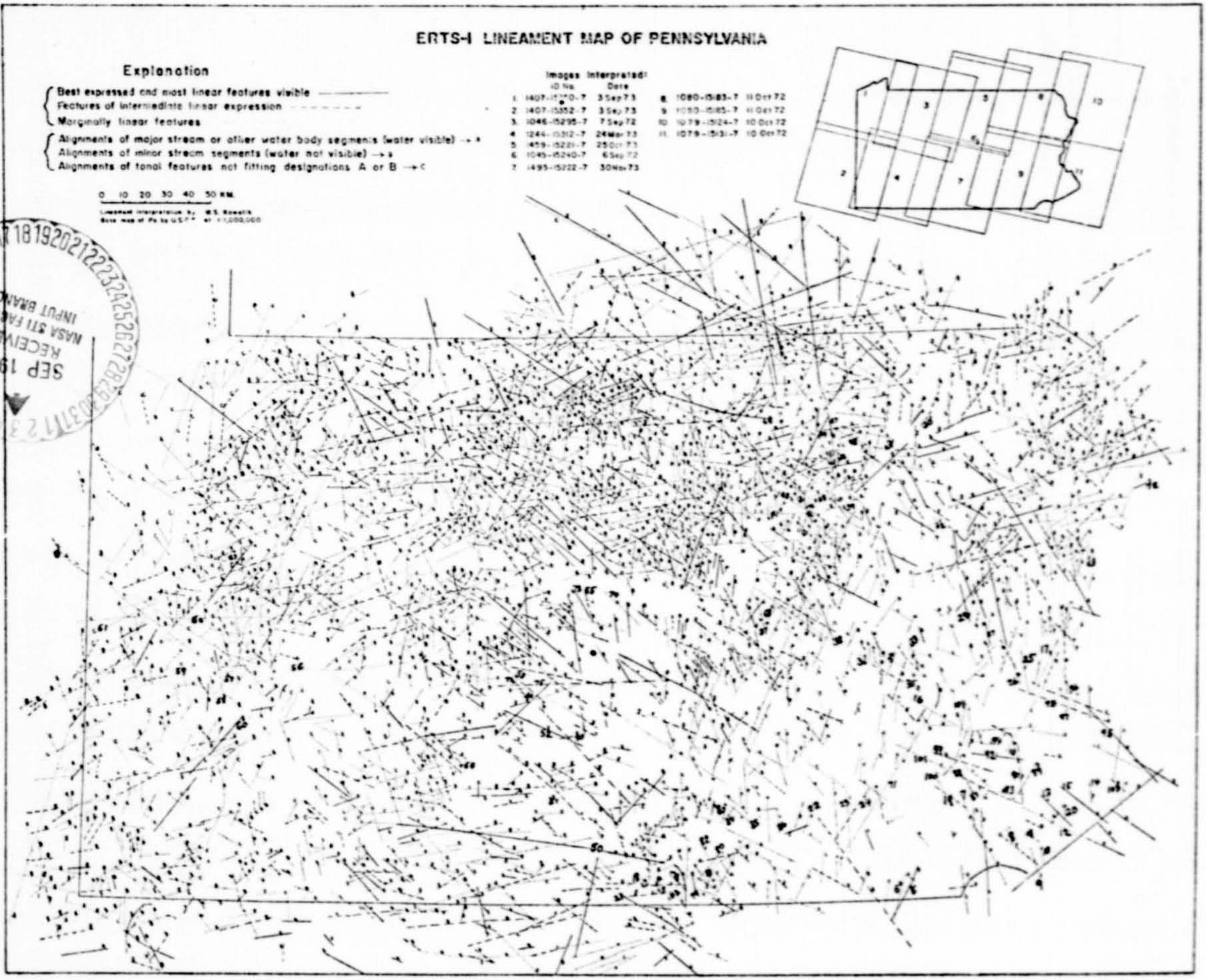
Table 6 (continued)

LINEAMENT			ASSOCIATED MINERALIZATION			Production
Number	Class	Type	Type	County Code	Name	Class
			R	Bucks 16	2.7 miles northeast of Point Pleasant	M
			R	Bucks 17	Delaware Quarry	M
96	1	B	O	Bucks 5*	Ferndale	M
			O	Bucks 4*	Kintnersville	M
97	2	C	O	Bucks 4*	Kintnersville	M
			O	Bucks 5*	Ferndale	M
98	2	C	R	Bucks 15	1.5 miles northeast of Pipersville	M
			R	Bucks 18	0.33 miles northeast of Point Pleasant	M
99	2	A	N	Berks 16	Frity Island Mine	H
			N	Berks 17	Raudenbush Mine	L
100	1	C	N	Berks 22	Grace Mine	H
			N	Berks 23	Byler's Mine	H?
101	1	C	N	Berks 18	Wheatfield Mine	H
			N	Berks 19	Ruth Mine	L
102	1	C	N	Adams 16	McNair Farm	P

Table 7: Miscellaneous Mineral Occurrences Associated with Lineaments.[a]

LINEAMENT			ASSOCIATED MINERALIZATION				Production
Number	Class	Type	Type	County	Code	Name	Class
103	2	B	S	Bucks	28	Vanartsdalen's Quarry	M
104	1	C	W	Berks	7	Flint Hill	M

[a]See footnotes to Table 4.


ERTS-1 LINEAMENT MAP OF PENNSYLVANIA
Explanation
Best expressed and most linear features visible
Features of intermediate linear expression
Marginally linear features
Alignments of major stream or other water body segments (water visible)
Alignments of minor stream segments (water not visible)
Alignments of tonal features not fitting designations A or B
0 10 20 30 40 50 KM.
Images Interpreted:
ID No. Date
1. 3 Sep 73
2. 1407-15352-7 3 Sep 73
3. 1046-15295-7 7 Sep 72
4. 1244-15312-7
5. 1459-15221-7
6. 1045-15240-7 6 Sep 72
7. 1495-15222-7
8. 1080-15183-7 11 Oct 72
10. 1079-15124-7 10 Oct 72
11. 1079-15131-7 10 Oct 72