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Geology of the Snake River Deposit

Crest Exploration Limited

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D. Miller

GEOLOGY OF THE SNAKE RIVER DEPOSIT

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GEOLOGY OF THE SNAKE RIVER PROSPECT

The geology of the Snake River hematite deposit was mapped during the summers of 1962 and 1963 by R. A. Stuart, A. E. Kliske and C. Riddell. Each of these geologists prepared reports which are in Crest's files. The geological work has been focussed upon the immediate economic aspects of iron formation geology and relatively little attention has been directed toward regional structure, stratigraphy nor to the genesis of the hematite beds and the related clastic sediments.

General Stratigraphy

The stratigraphic sequence at Snake River is broken into three gross units by two major unconformities. The uppermost unit consists of carbonate formations varying in age from Cambrian to Devonian. These carbonate formations are fairly consistent, widely distributed and generally recognized throughout this part of the Yukon and Northwest Territories. The upper unconformity is a major one and the carbonates rest upon a variety of rocks, some of which are generally believed to be Cambrian and others believed to be Precambrian. At Snake River the rocks below the unconformity are a shaly conglomerate overlain, where they have not been eroded, by shales with some carbonate. The unconformity below the conglomerate is a major one which truncates the underlying carbonate sequence. The general relationships are shown in the diagrammatic stratigraphic cross section.

The oldest rocks exposed within the map area comprise a thick sequence of variably resistant quartzite, conglomerate, carbonate and minor black shale. This sequence is overlain by a relatively thin black shale unit followed by a very massive light grey cliff-forming limestone and a thick sequence of recessive buff-weathering carbonates and shaly carbonates with a distinctive gypsum shale member near the base and several resistant carbonate members in the upper portion. These rocks are grouped together as map-unit 1 on the geological map. No fossils have been collected from these rocks within the map area, but rocks thought to be correlative have yielded Lower Cambrian fossils at a locality some 20 miles southeast of the area. There is a distinct possibility that these rocks may be Precambrian, as suggested by Dr. L. Green of the Geological Survey of Canada.

A marked angular unconformity bevels the strata of map unit 1, and as much as 3500 feet of stratigraphic truncation can be recognized within the map area. The unconformity is quite planar with no relief of consequence. It is overlain by the Rapitan formation consisting of 5000 feet or more of silty conglomerate and conglomeratic shale and siltstone (map unit 2) which pass upward into the shales of map unit 3. The lower 2000 to 3000 feet of the conglomerate and siltstone are usually highly ferruginous, dark maroon in colour, with iron formation at several horizons in the lower 1000 feet. The upper part of the sequence is dominantly grey-green in colour, though some highly ferruginous maroon beds are present.

The conglomerates pass upward in the southern part of the area to dark grey shales. The lower 1000 feet of map unit 3 are mostly shale but the middle 2000 feet consists of alternating shales and carbonate bands, each 200 to 500 feet in thickness, with one quartzite horizon in the upper part. The uppermost 1000 to 1500 feet of map unit 3 is light yellow-brown weathering, silty, argillaceous, occasionally sandy, platy to massive dolomite with ripple marks, mud cracks and worm trails. Some very poorly preserved fossil remains also found.

DIAGRAMMATIC STRATIGRAPHIC CROSS SECTION

SHOWING NORTHWARD TRUNCATION OF MAP UNITS 2 AND 3

MAP UNITS	PERIOD	APPROXIMATE THICKNESS
7	MID. DEVONIAN	1000'
6	SILURO-DEVONIAN	2000'
5	SIL. ORDOVICIAN	1000'
4	ORDOVICIAN	500'
	U & M. CAMBRIAN	1000 - 1500'
3	CAMBRIAN ?	4500 - 5000'
2	CAMBRIAN ?	7000'+
1	CAMBRIAN ?	8000'+

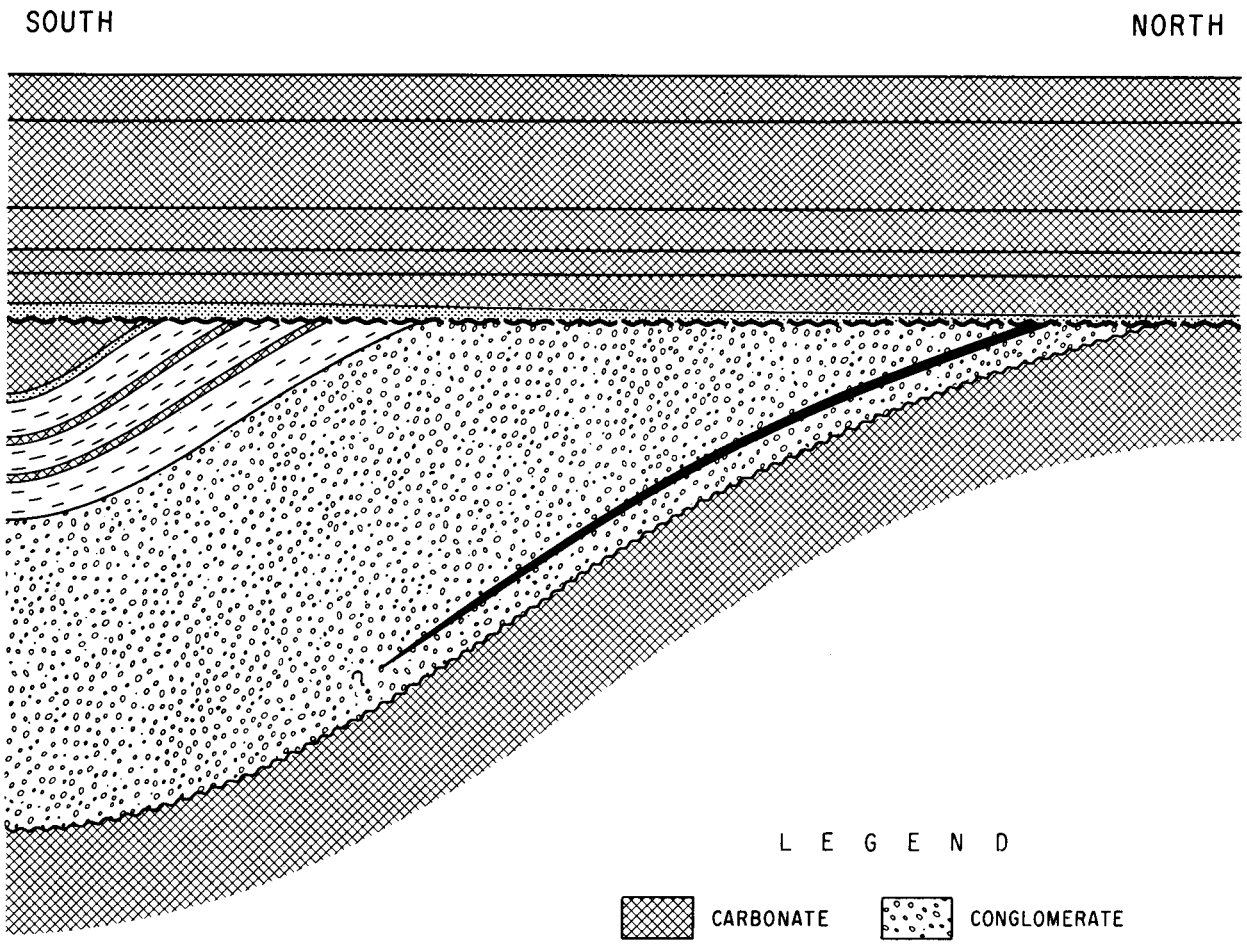


TABLE OF FORMATIONS

Period	Lithology	Approximate Thickness	Map Unit	Probable Correlation
Middle Devonian	Dark grey carbonate	1000'?	7	Hume
Siluro-Devonian	Upper buff carbonate Light grey carbonate Lower buff carbonate	2000'+	6	Lone Mountain & Bear Rock
Siluro Ordovician	Medium grey blocky carbonate	1000'	5	Ronning
Cambro Ordovician	Shaly carbonate. Light grey blocky carbonate	500' 1000'	4	
- - - - - - - - - - - - - - Angular Unconformity - - - - - - - - - - - - - - - -				
Cambrian	Silty dolomite. Shale with carbonate and quartzite Dark shale.	1500' 2000' 1000'+	3	?
	Green & red conglomerate with iron formation	7000'+	2	Rapitan
- - - - - - - - - - - - - - Angular Unconformity - - - - - - - - - - - - - - - -				
Cambrian (?)	Recessive buff-weathering carbonate with occasional zones of shale and resistant carbonate.	2500'+		
	Gypsum and shale	500'		
	Buff-weathering shaly carbonate and carbonate	500'	1	MacDougal ?
	Grey resistant limestone	1000'		
	Black shale.	500'		
	Quartzite, conglomerate, carbonate and shale	3000'+		

Map units 2 and 3 may be either Cambrian or Precambrian. The evidence, which is discussed in a subsequent section, is inconclusive.

The conglomeratic beds are overlain by a major angular unconformity that truncates at least 6000, and possibly as much as 12,000 feet of stratigraphic section within the limits of the map area. The regional dip of the strata below the unconformity is to the south and successively older beds are present at the unconformity from south to north. A varying degree of angularity between strata above and below the unconformable surface establishes the fact that there was at least gentle folding prior to the erosional episode, but there does not appear to have been any wide-spread severe pre-unconformity deformation. The unconformity is overlain by a conformable sequence of carbonate and shaly carbonate ranging in age from Late Cambrian to Middel Devonian. The Late Cambrian is represented by light-coloured grey and buff weathering limestone and dolomite with, commonly, a basal quartzite immediately overlying the unconformity. Two collections from the fossiliferous Late Cambrian were identified by B. H. Howell of Princeton University. The first collection was made from the lower 300 feet of map unit 4 on the west side of Discovery Creek at IF-138-63, which is on the northern side of the iron formation outcrop. The trilobite fauna were referable to the following genera:

Parabolinella sp. (probably an undescribed species)

Lotagnostus sp. (undescribed species)

Pseudagnostus sp. (a small species, probably undescribed)

This fauna appears to be new. Although the genera are typically Upper Cambrian, the species are undescribed ones.

The second collection was made from the basal quartzite of unit 4 at latitude 65° 04 longitude 132° 35 which is at the southern margin of the map area. At this location the basal quartzite contains trilobites that are probably from the Wenkohemnia-Stephenaspis Zone of the Middle Cambrain. Most of these trilobites are not very well preserved, but they appear to be referable to the following species:

Piazella tuberculate Rasetti

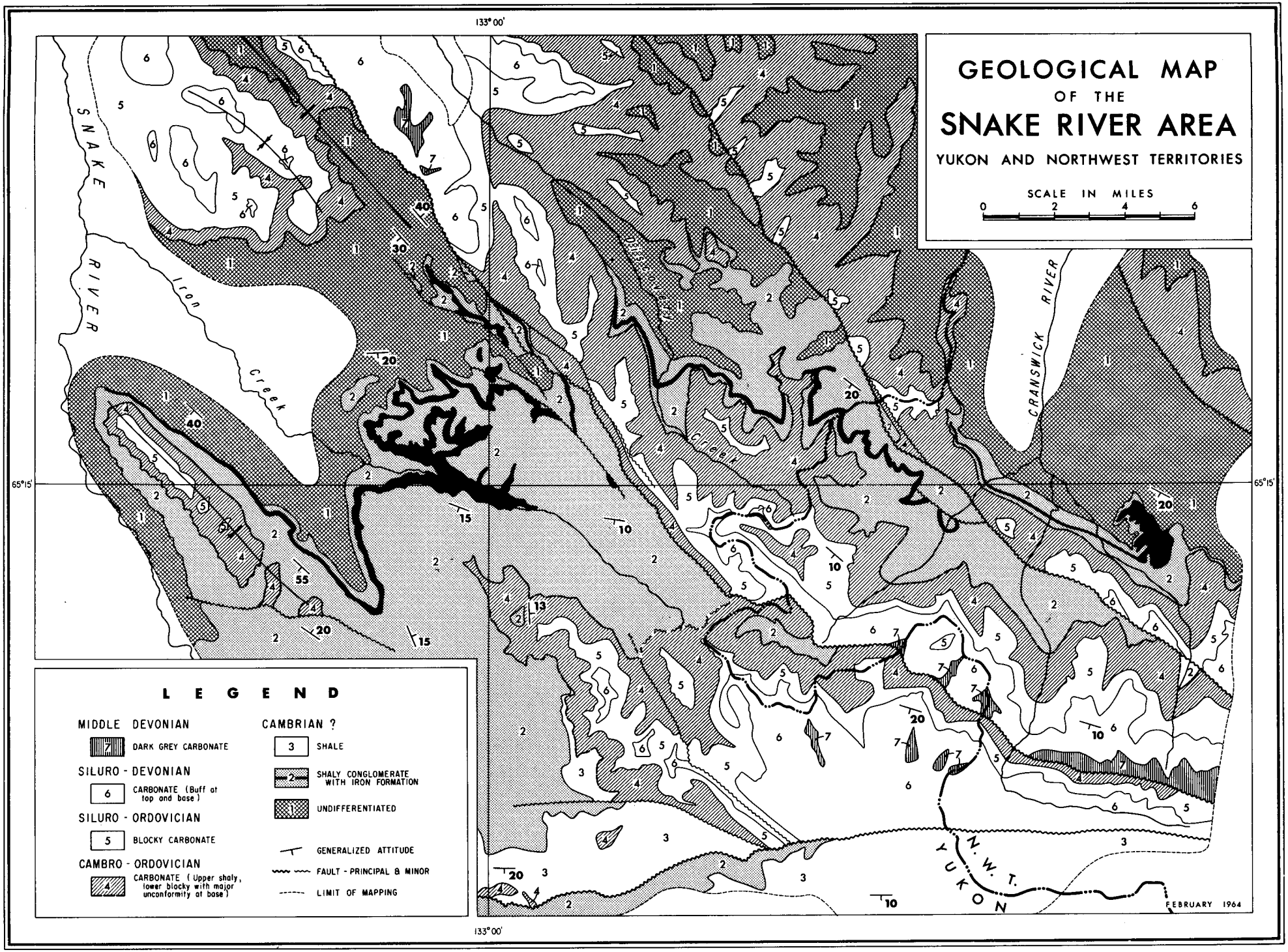
Amecephalus agnesansis Walcott

Syspacephalus laevigatus Rasetti

Syspacephalus gregarius Rasetti

There is also a little brachiopod on one piece of this sandstone that is referable to Eoorthis or some similar genus and resembles a brachiopod that occurs in the Middle Cambrian of Newfoundland.

The fossil evidence indicates a middle and upper (?) Cambrian age for the lowermost part of the through going carbonates above the upper unconformity. The light carbonate in the lower part of map unit 4 is overlain by a dark grey-weathering recessive sequence of graptolitic argillaceous limestone and limestone of Early and Middle Ordovician age (map unit 4), followed by massive, medium-grey weathering fossiliferous dolomite of Upper Ordovician


133° 00'
65° 15'
SNAKE RIVER
Iron Creek
CRANSWICK RIVER
N.W.T.
YUKON
GEOLOGICAL MAP
OF THE
SNAKE RIVER AREA
YUKON AND NORTHWEST TERRITORIES
SCALE IN MILES
0 2 4 6
LEGEND
MIDDLE DEVONIAN
7 DARK GREY CARBONATE
SILURO - DEVONIAN
6 CARBONATE (Buff at top and base)
SILURO - ORDOVICIAN
5 BLOCKY CARBONATE
CAMBRO - ORDOVICIAN
4 CARBONATE (Upper shaly, lower blocky with major unconformity at base)
CAMBRIAN ?
3 SHALE
2 SHALY CONGLOMERATE WITH IRON FORMATION
1 UNDIFFERENTIATED
GENERALIZED ATTITUDE
FAULT - PRINCIPAL & MINOR
LIMIT OF MAPPING
FEBRUARY 1964

and Silurian age (map unit 5). This dolomite is separated from the overlying massive light grey limestone and dolomite by a zone of buff-weathering dolomite. Neither the buff-weathering nor the massive grey carbonate contains diagnostic fossils and they may be either Silurian or Devonian in age. They are overlain by a thin orange-buff weathering dolomite (map unit 6), followed by fossiliferous light to dark grey Middle Devonian limestone (map unit 7). At the mountain front north of the map area the Middle Devonian limestone is overlain by Upper Devonian black shale, which dips northward beneath Cretaceous sandstones and shales underlying the Peel Plateau to the north and east.

Stratigraphy of Rapitan Formation

General

The name Rapitan Formation was given to the shaly conglomerate unit in which the Snake River iron formation occurs by geologists of the Geological Survey of Canada. The base of the Rapitan (map unit 2) is marked by a prominent angular unconformity (Figure 1, page 7) which overlies the strata of map unit 1, and the top of the Rapitan is formed over most of the area by a second major angular unconformity (Figure 2, page 7). In the southern most part of the Snake River map area, however, the Rapitan is directly overlain by up to 4,000 feet of shales with some carbonate and quartzite (map unit 3). This unit is not present over the rest of the map area since it is truncated to the north by the upper unconformity.

The age of the Rapitan formation has not been firmly established. In the Snake River area the conglomerates (unit 2) are conformably overlain by shales (unit 3) with poorly preserved fossils of indeterminate age. In prospecting on Nash Creek, a tributory of the Wind River, some 75 miles west of the Snake River, M. Chernoff's party found 2500 feet of red sandstone, conglomeratic shale and a little poor iron formation unconformably overlying presumed Precambrian (Tindir?) quartzite and phyllites and overlain by trilobite bearing middle or upper Cambrian carbonates. This red clastic sequence is believed to be the same unit which contains the iron formation. One single specimen of a lingula was found in the shale of this unit. This evidence suggests that the conglomerates are Cambrian rather than Precambrian.

The Rapitan has subsequently been recognized by Calstan geologists 200 to 250 miles southeast of Iron Creek in the Redstone River area near Dal and June Lakes. In this area the Rapitan is overlain by some 10,000 feet of shales, up to 3,000 feet of quartzite, followed by olenellus bearing lower Cambrian carbonates. The presence of this large thickness of sediment separating the Rapitan from lower Cambrian carbonates suggests that the Rapitan may indeed be Precambrian, an opinion which is also held by several geologists of the Geological Survey. In the main Iron Creek area the thickness of the Rapitan was determined at section (WG-1-63) which is in the vicinity of IF-216-63. In this section there was a measured thickness of 6,693 feet which, together with an estimated 500 to 700 feet of erosion on the unconformity at this locality, gives a total pre-erosion thickness for the Rapitan of 7,200 to 7,500 feet.



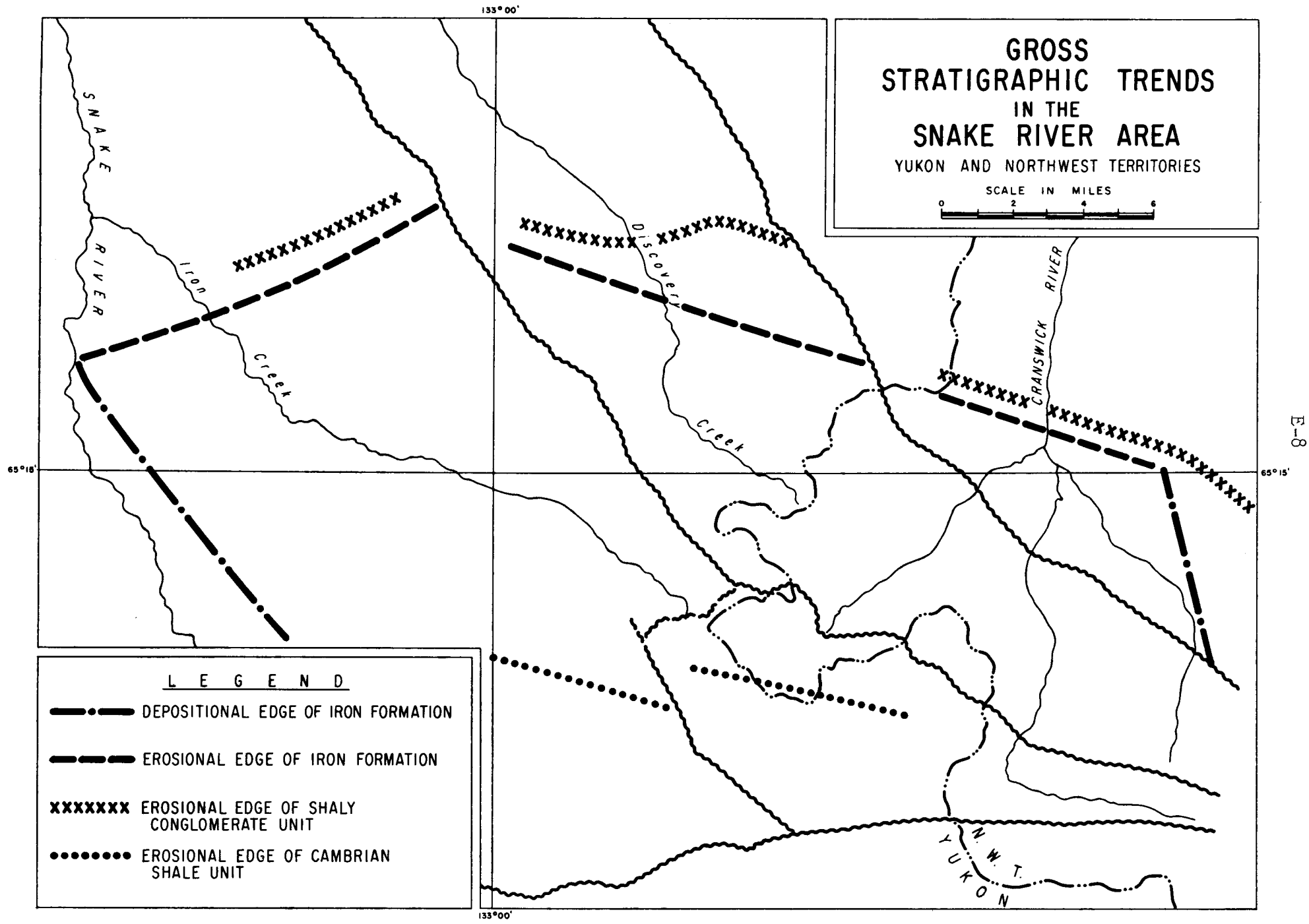
Figure 1

Angular unconformity at base of Rapitan Formation



Figure 2

Angular unconformity at top of Rapitan Formation


GROSS
STRATIGRAPHIC TRENDS
IN THE
SNAKE RIVER AREA
YUKON AND NORTHWEST TERRITORIES
SCALE IN MILES
0 2 4 6
133°00'
65°18'
65°15'
SNAKE RIVER
Iron Creek
Discovery Creek
CRANSWICK RIVER
N.W.T.
YUKON
LEGEND
DEPOSITIONAL EDGE OF IRON FORMATION
EROSIONAL EDGE OF IRON FORMATION
EROSIONAL EDGE OF SHALY CONGLOMERATE UNIT
EROSIONAL EDGE OF CAMBRIAN SHALE UNIT

The diagram of "Gross Stratigraphic Trends in the Snake River Area" illustrates the northward truncation of the conglomerate by the unconformity. Similarly, both to the east and to the west, the conglomerate thins very rapidly but this is only partially due to truncation by the upper unconformity as there is also some onlap of the lower part of the conglomerate unit on the lower unconformity. This is shown by the depositional edge on the iron formation to the east and the west. Beyond the depositional edge of the iron formation there is also a zero edge to the conglomerate which is more a consequence of erosion on the upper unconformity than of onlap on topography of the lower unconformity.

The lower 2000 to 3000 feet of the conglomerate and siltstone are usually highly ferruginous, dark maroon in colour, with iron formation at several horizons in the lower 1000 feet. The upper part of the sequence is dominantly grey-green in colour, though some highly ferruginous maroon beds are present. The coarse fragmental material in the conglomeratic rocks probably represents less than 10% of the volume of the rocks, and most of the beds should properly be called conglomeratic siltstone. The fragments are rounded to subangular, range in size from sand grains to boulders over 15 feet long, and consist of carbonate, basic igneous rock, sandstone, quartzite and shale, in order of decreasing abundance. Beds of true conglomerate, sandstone, siltstone and shale occur at numerous horizons throughout the conglomeratic sequence. The whole series has a gross stratification which is clearly evident from a distance, but individual outcrops appear to be massive and without any stratification whatever.

Stratigraphy of the Iron Formation

Thirteen cross sections were constructed to establish correlations in the iron-rich zone throughout the Snake River map area. Eight of these cross sections form a grid (4 east-west and 4 north-south) covering the main Iron Creek block, two follow the outcrop area on the east and west side of South Iron Creek, and three follow the outcrop area from the Iron Creek block through the Discovery Creek block to the eastern limits of the Cranswick River block (see location map). The original cross sections which were drawn to a vertical scale of 20 feet per inch and a horizontal scale of 500 feet per inch from the detailed Rock Log Charts, have been simplified and reduced for this report.

The sections were hung on the top of the lower marker sandstone as datum, except for the east half of cross section No. 13, where it was necessary to use a sub-datum. The lithologies were standardized for facility in correlation into five types: hematite, shale, sand, shaly conglomerate (less than 30% to 40% fragments) and conglomerate (more than 30% to 40% fragments). These subdivisions were quite satisfactory except they do not provide for shaly hematite which is an intermediate rock type. The arbitrary ore cutoff of 35% iron was used to differentiate between hematite and shale. During the correlation work, the iron formation zone was divided into nine natural units, the boundaries of which were established as follows:

Zone 1: Top of main iron to bottom of upper marker sandstone.

Zone 2: Bottom of upper market sandstone to top of first continuous clastic unit.

Zone 3: Top of first continuous clastic unit to bottom of second clastic unit.

Zone 4: Top of second continuous clastic unit to bottom of main marker sandstone.

Zone 5: Bottom of main marker sandstone to top of next major clastic unit.

Zone 6: Major clastic unit - predominantly shaly conglomerate.

Zone 7: Major hematite unit.

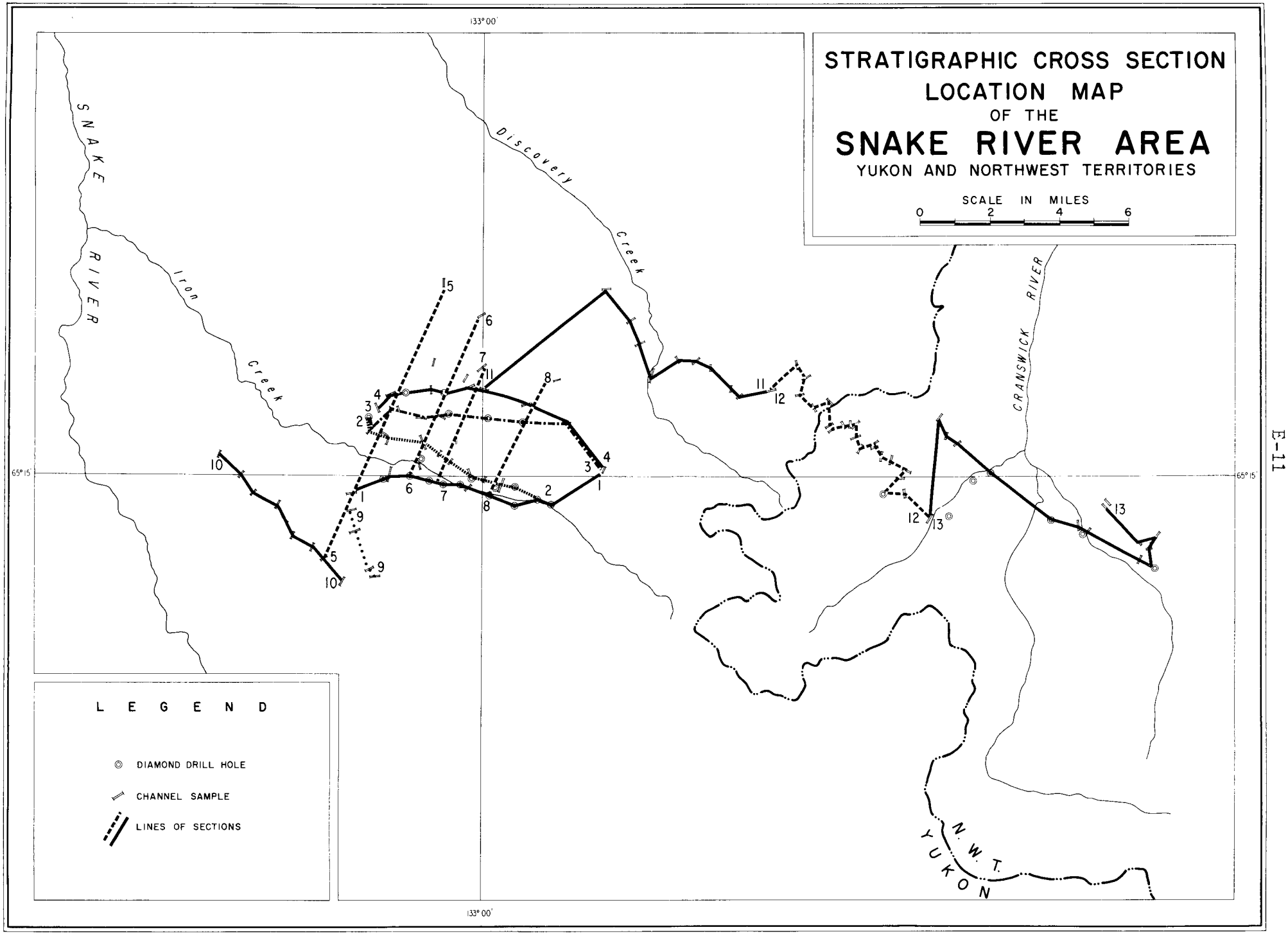
Zone 8: Major clastic unit - predominantly shaly conglomerate.

Zone 9: Last major hematite unit.

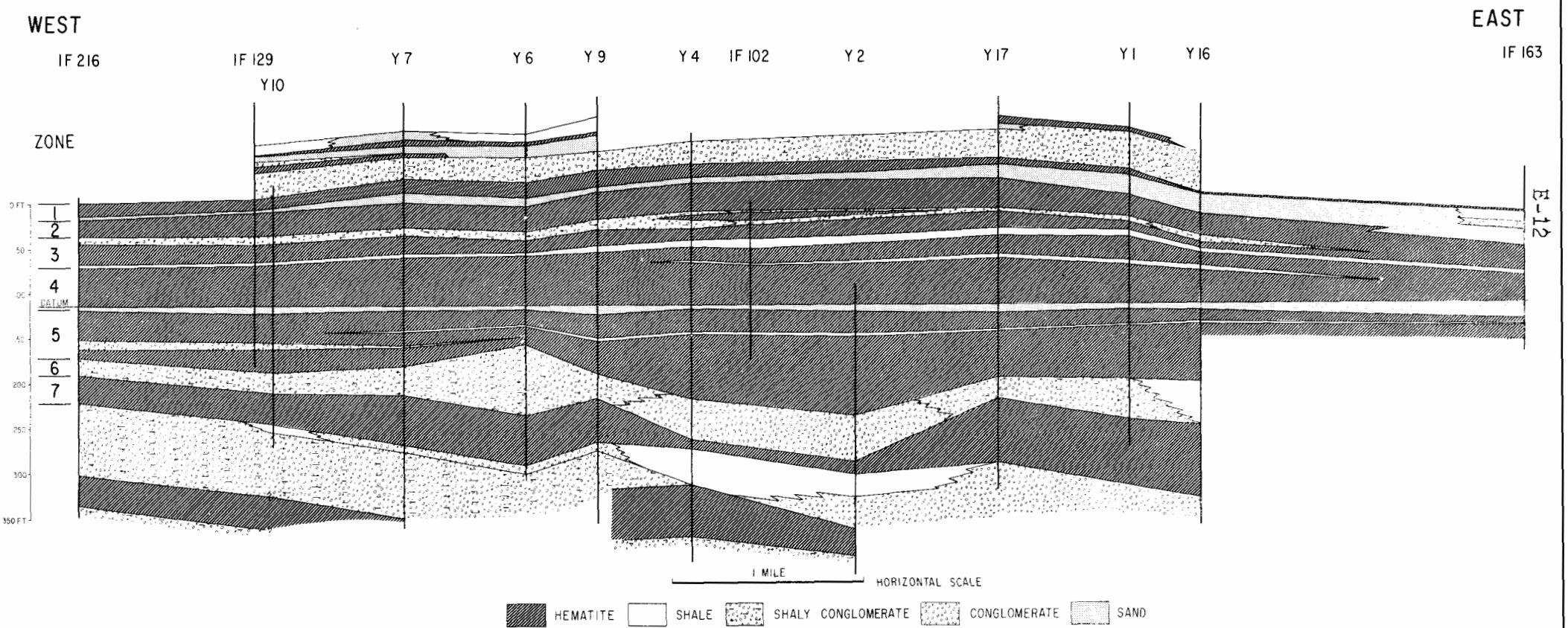
Correlations were made mainly upon lithologic and isopach data, but later on when it was apparent that there were grade differences from zone to zone it was occasionally necessary to use both iron and phosphorus assays. While the correlations in the Iron Creek block were reasonably straight forward, the correlation across to the Discovery Creek block and to the Cranswick River block were quite difficult and extensive use was made of phosphorus assays as a correlation tool.

The stratigraphic and areal distribution of the iron formation and the clastic rocks in the iron-rich zone is seen on these cross sections. The persistence of the sandstone beds and the tendency of the conglomerate and shaly conglomerate beds to change thickness abruptly or to pinch out entirely are quite apparent. The difference between shale and shaly conglomerate is only a matter of pebble or boulder content. Although it is not surprising perhaps, it is interesting to see the rapid lateral variation from one rock type to another because it illustrates that both have had a common mode of origin. The cross sections also illustrate the manner in which the iron formation is concentrated in three main units: a 100 to 250 foot section (Zones 1 to 5); a 10 to 80 foot section (Zone 7); and a 20 to 50 foot section (Zone 9) at the bottom. The upper unit of iron formation (Zones 1 to 5) has been traced continuously from the Snake River to the Cranswick River (Figure 1, page 29). It is thickest in the area north of Iron Creek and thins to the southwest and to the east, apparently by an interfingering with, and ultimate replacement by, conglomerate and shaly conglomerate in the upper and lower parts of the zone.

Zone 7 is also a fairly persistent unit, although it tends to incur radical changes in thickness. This zone has been traced into the Discovery Creek block but is not seen again until the easternmost limits of the Cranswick River block. At this point the correlation is doubtful as it was made chiefly on the basis of the lower phosphorus assays usually present at this horizon. Zone 9 is present in the Iron Creek block, although poorly exposed, but it has not been observed in the Discovery Creek area or Cranswick River area, except where Zone 7 is present on the latter's eastern limit.

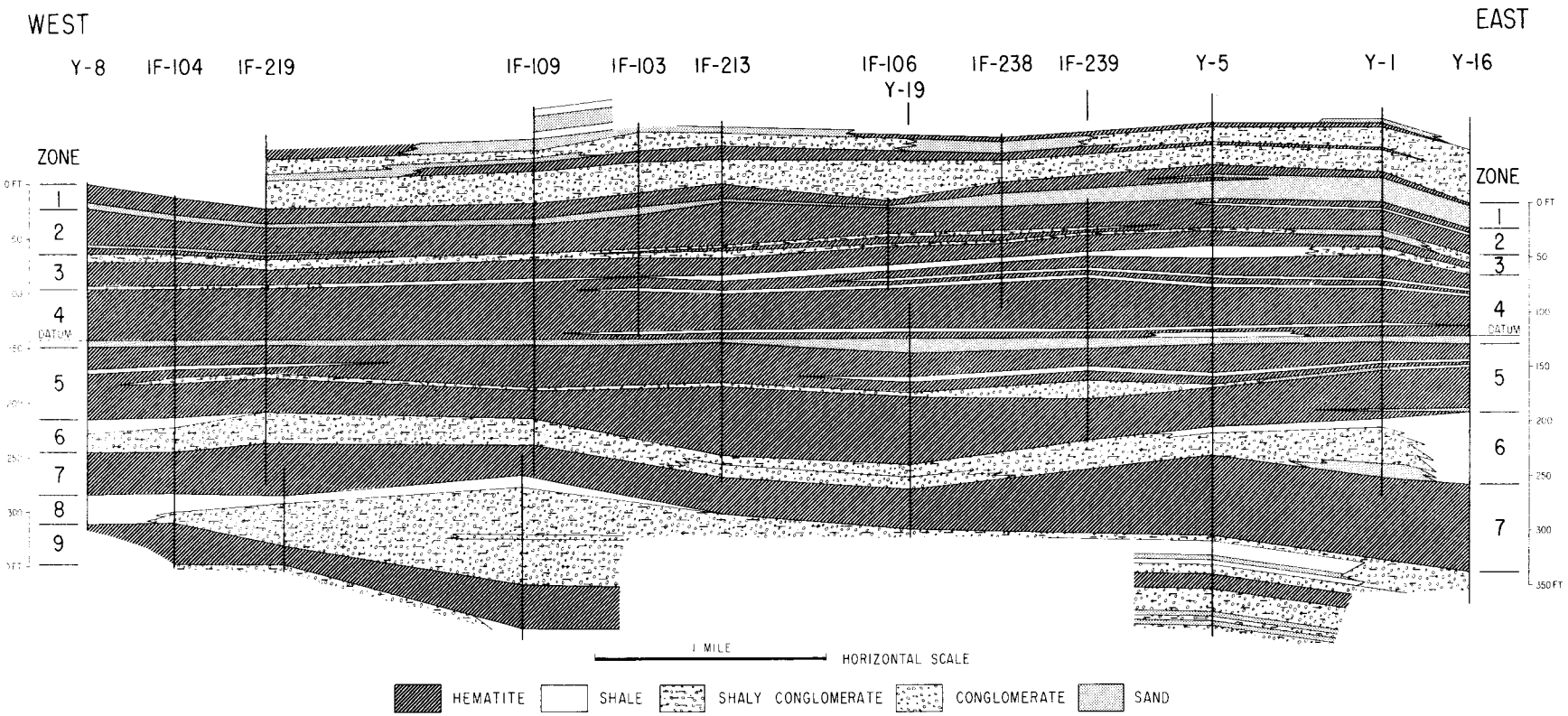

133° 00'
65° 15'
SNAKE RIVER
Iron Creek
Discovery Creek
CRANSWICK RIVER
N.W.T.
YUKON
STRATIGRAPHIC CROSS SECTION
LOCATION MAP
OF THE
SNAKE RIVER AREA
YUKON AND NORTHWEST TERRITORIES
SCALE IN MILES
0 2 4 6
L E G E N D
DIAMOND DRILL HOLE
CHANNEL SAMPLE
LINES OF SECTIONS

STRATIGRAPHIC CROSS SECTION No. 1
IRON CREEK AREA

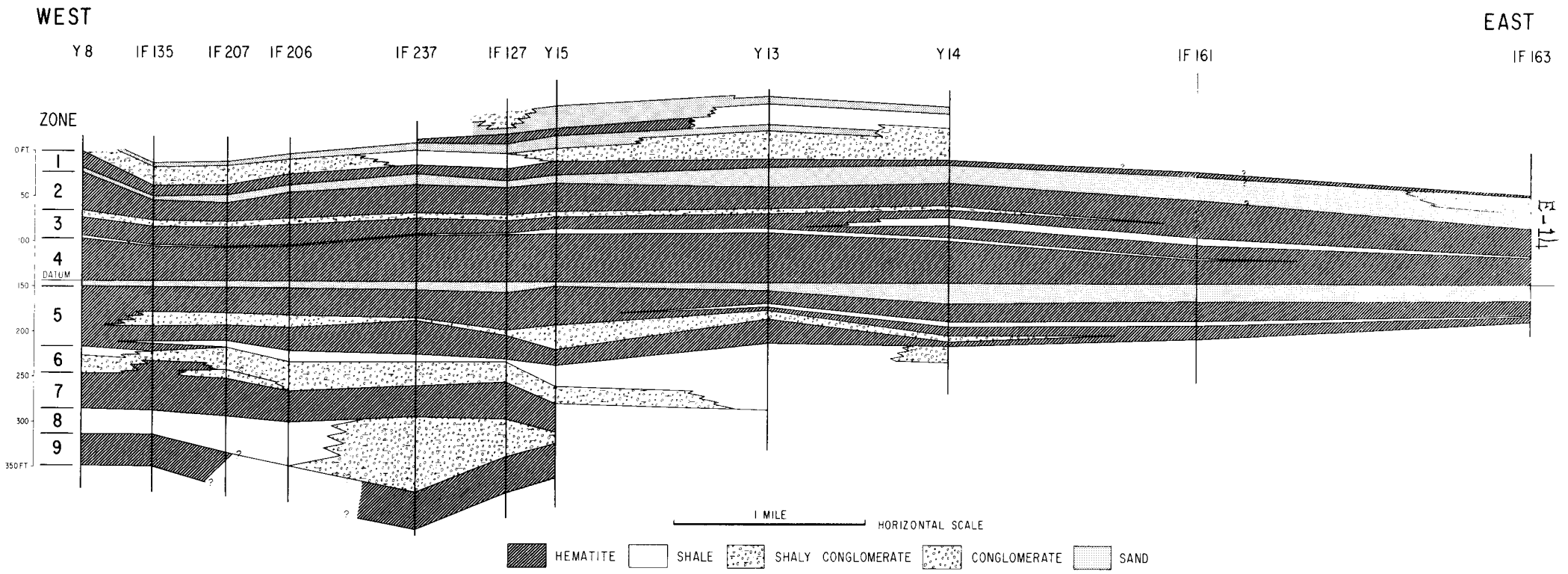


E-12

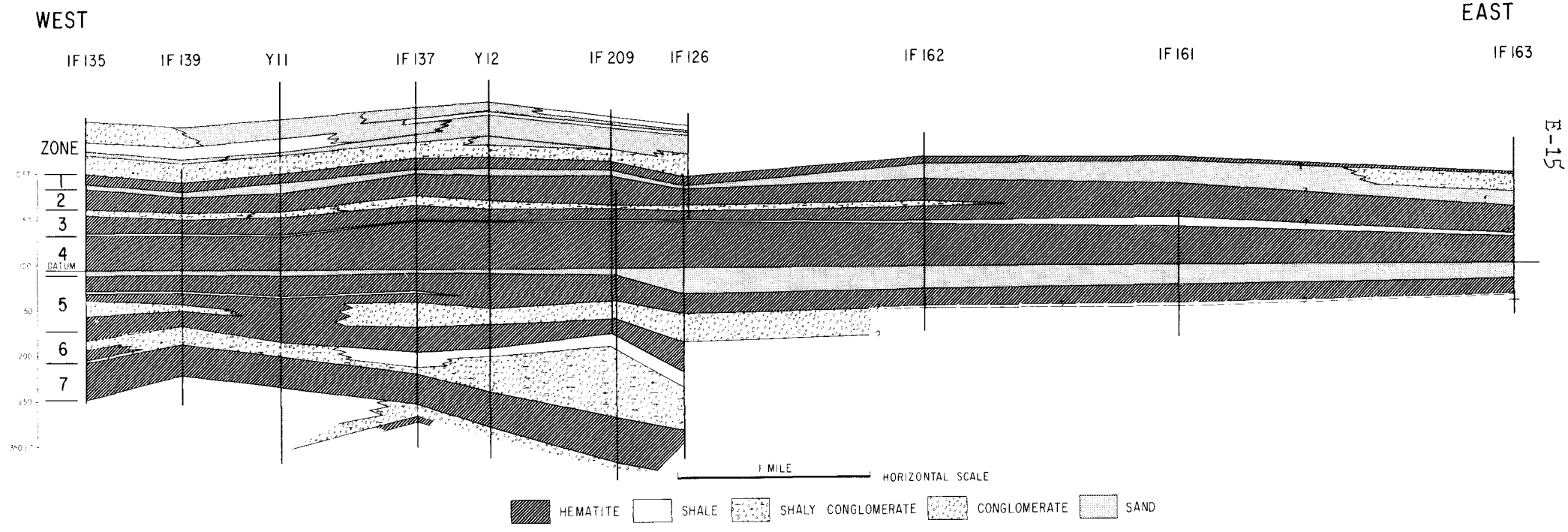
STRATIGRAPHIC CROSS SECTION No. 2
IRON CREEK AREA



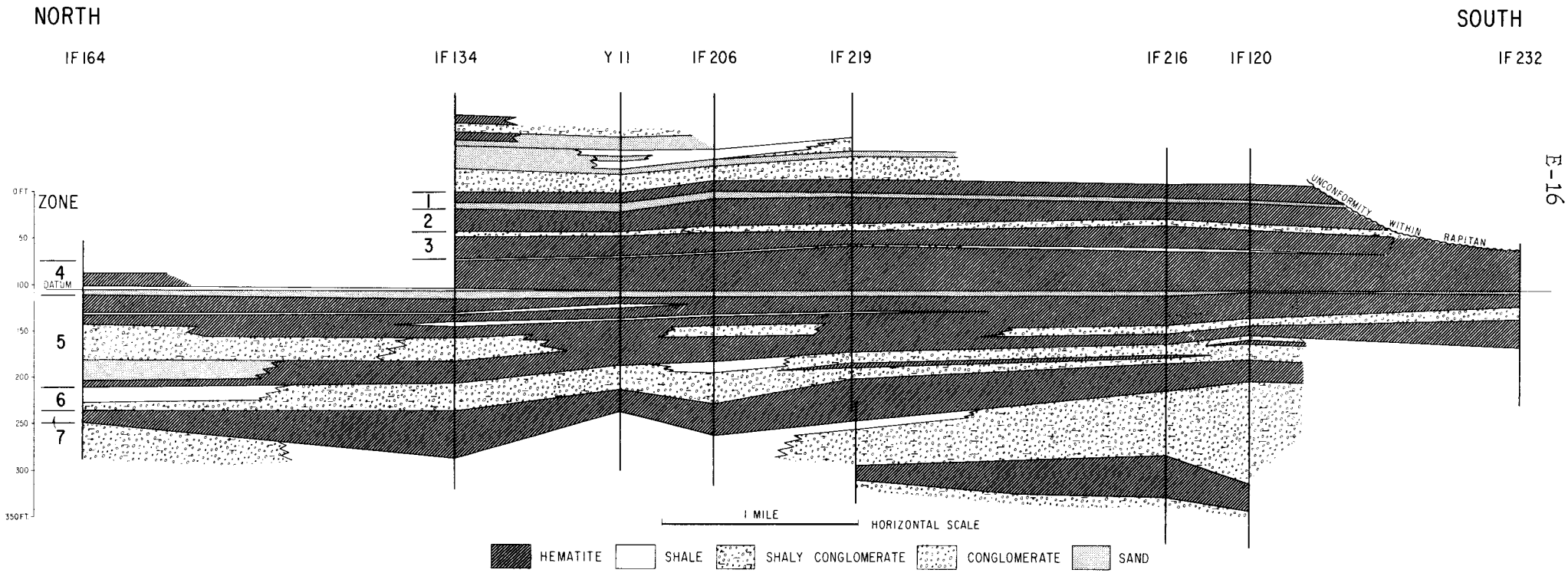
STRATIGRAPHIC CROSS SECTION No. 3
IRON CREEK AREA



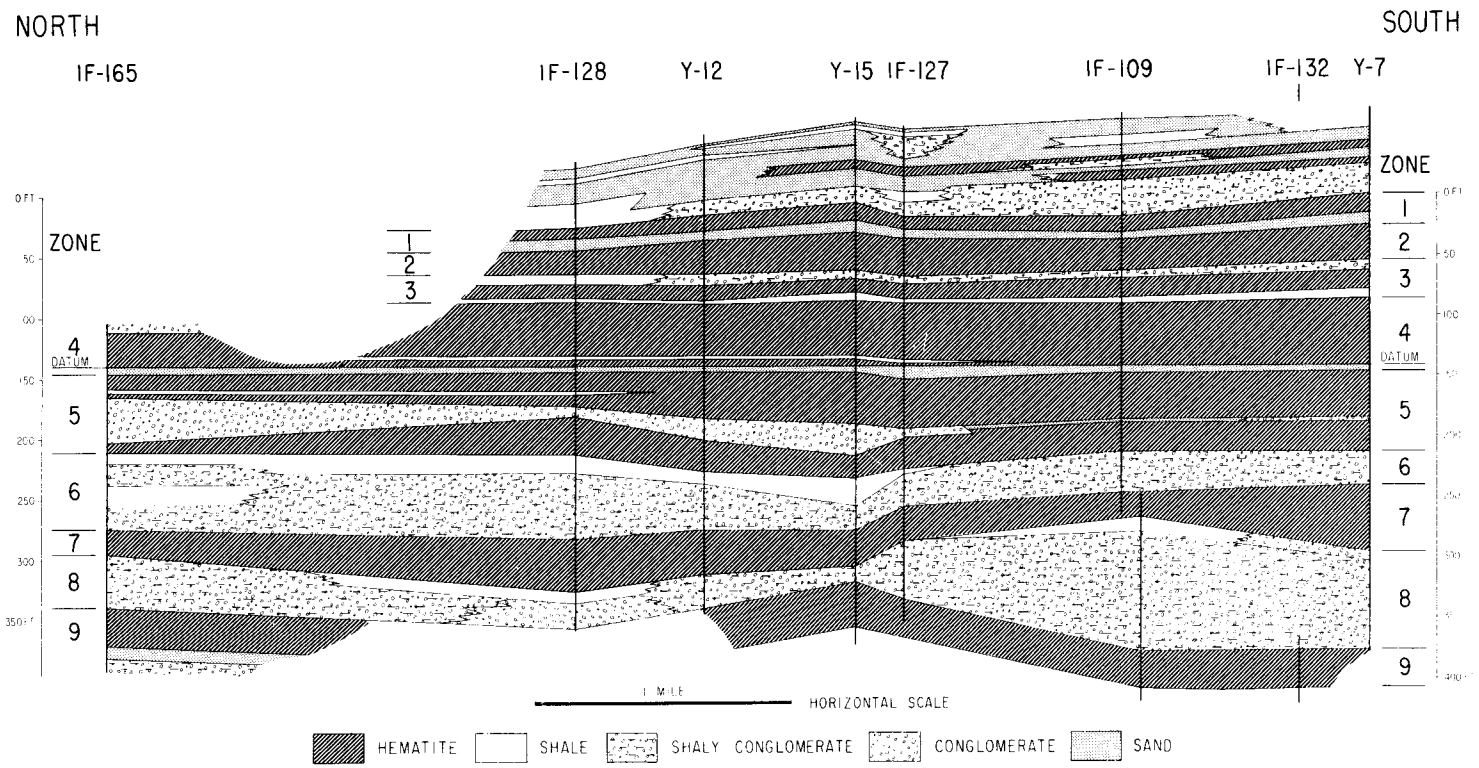
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IRON CREEK AREA



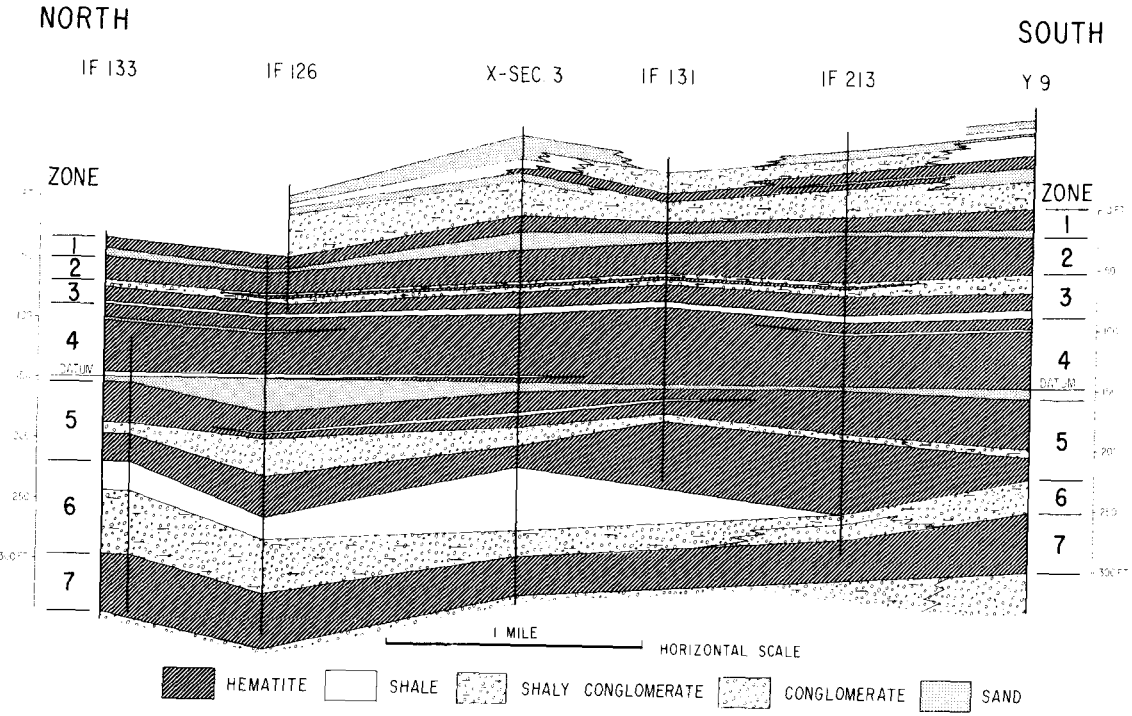
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IRON CREEK AREA



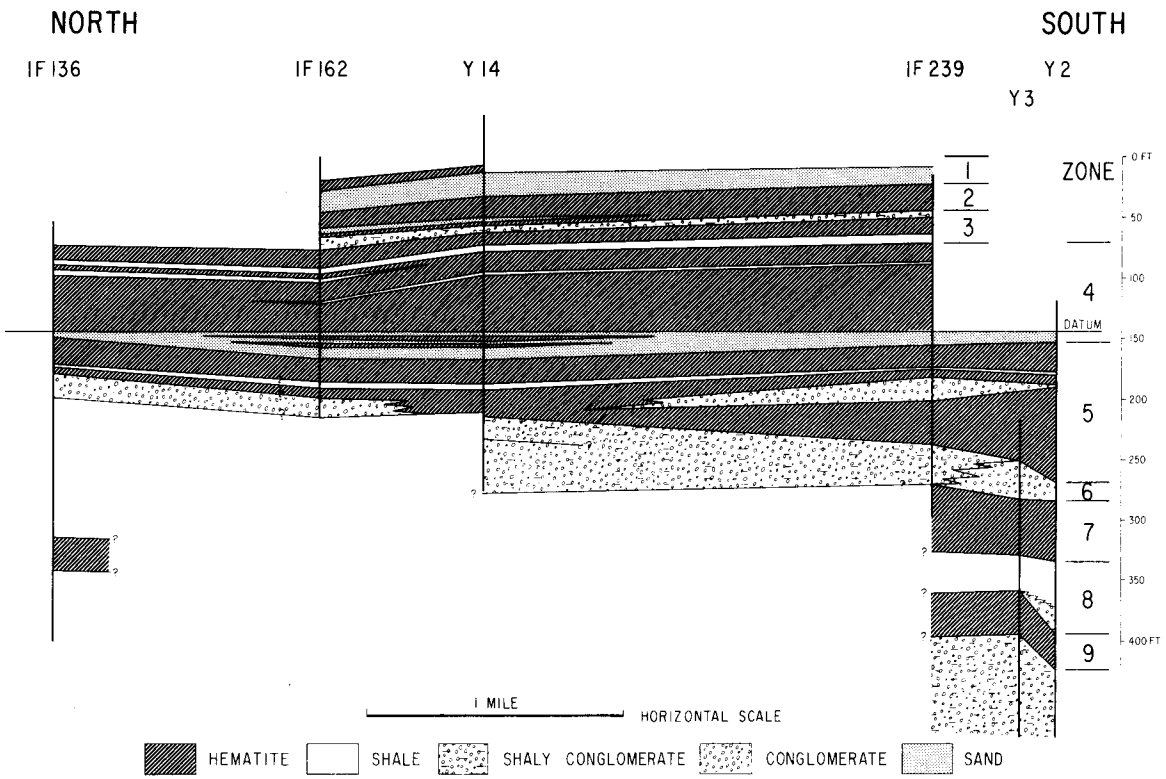
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IRON CREEK AREA



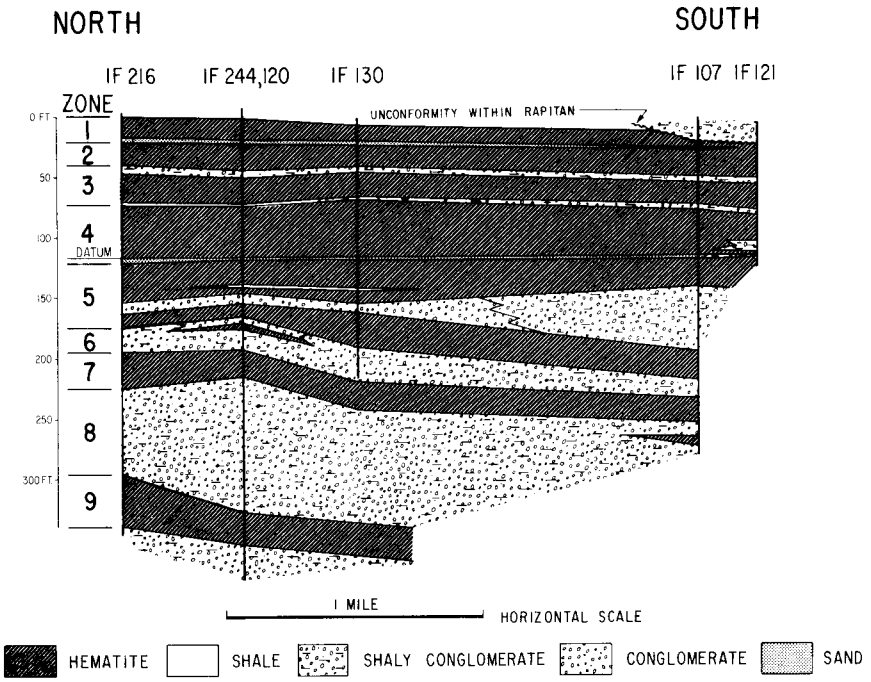
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IRON CREEK AREA



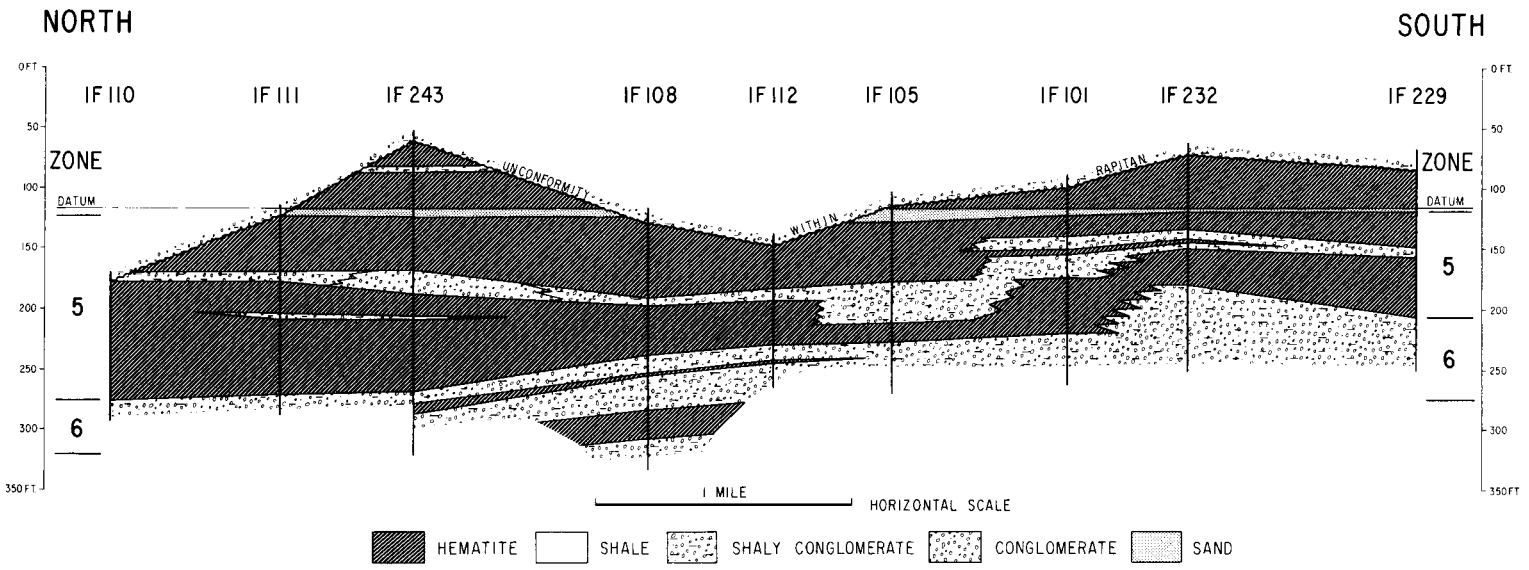
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IRON CREEK AREA



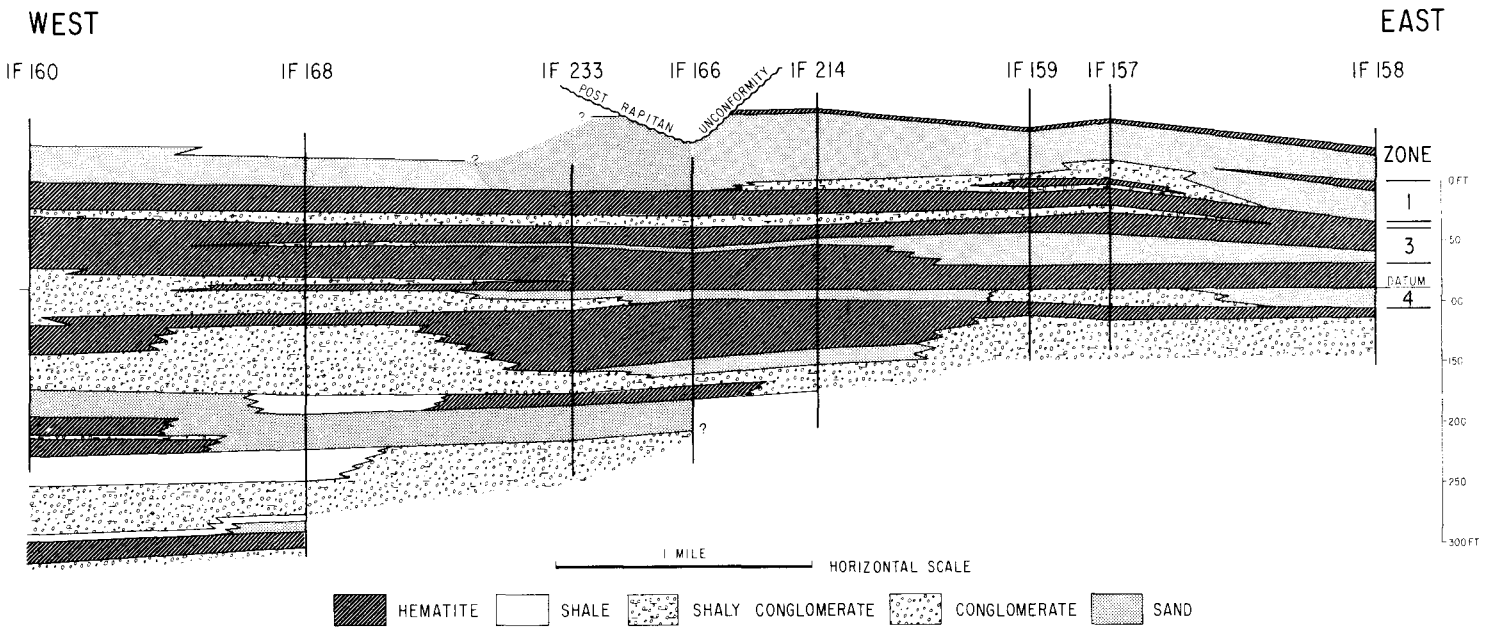
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IRON CREEK AREA



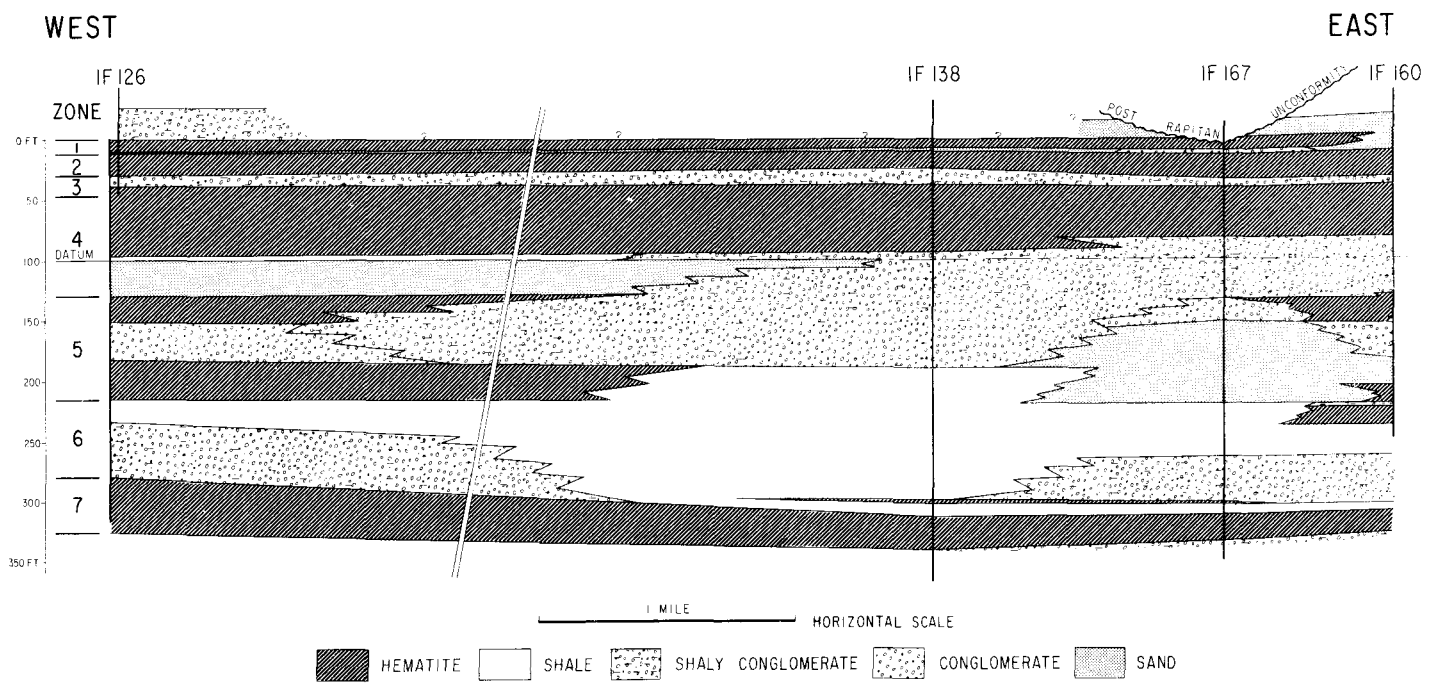
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IRON CREEK AREA



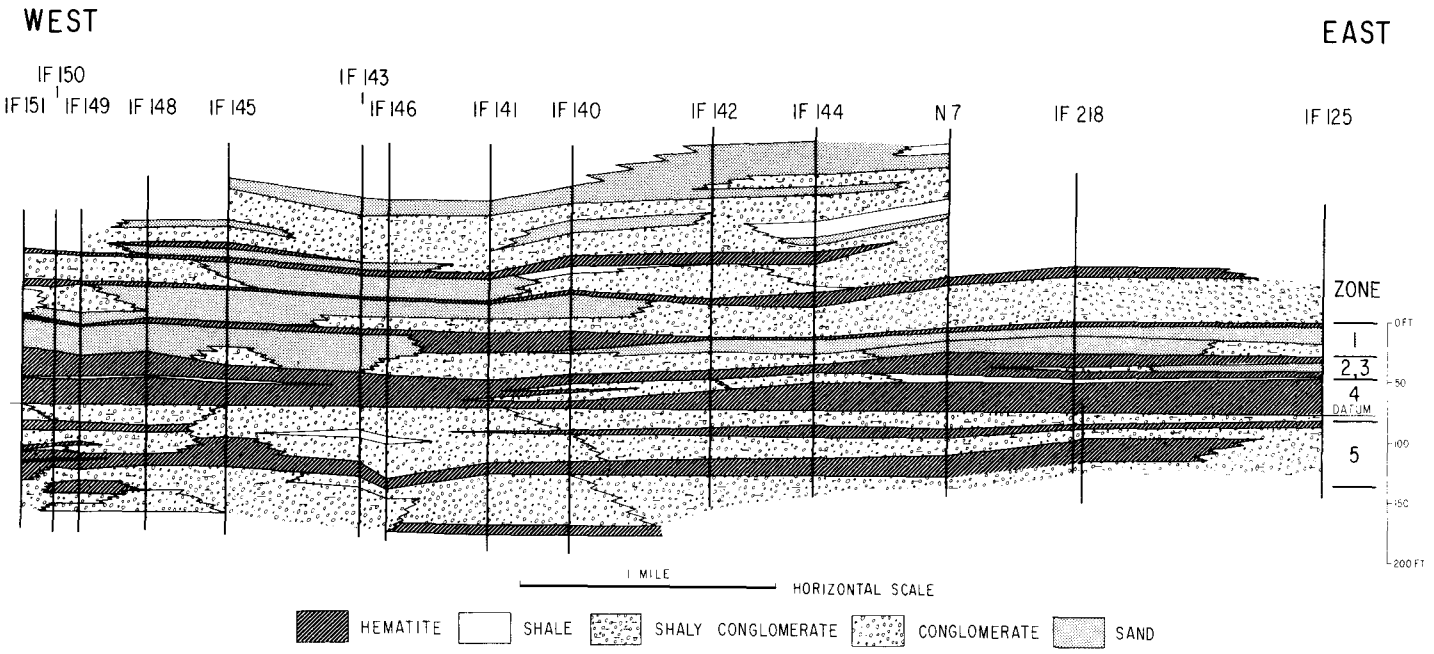
STRATIGRAPHIC CROSS SECTION No. II (EAST HALF)
DISCOVERY CREEK AREA



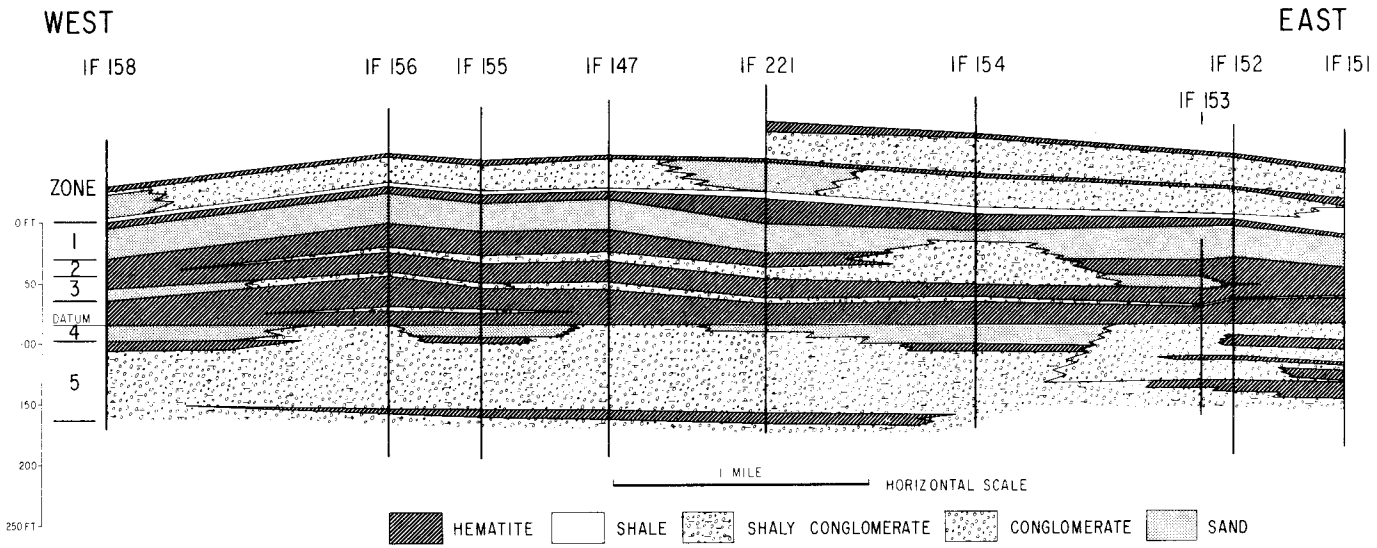
STRATIGRAPHIC CROSS SECTION No. II (WEST HALF)
DISCOVERY CREEK AREA



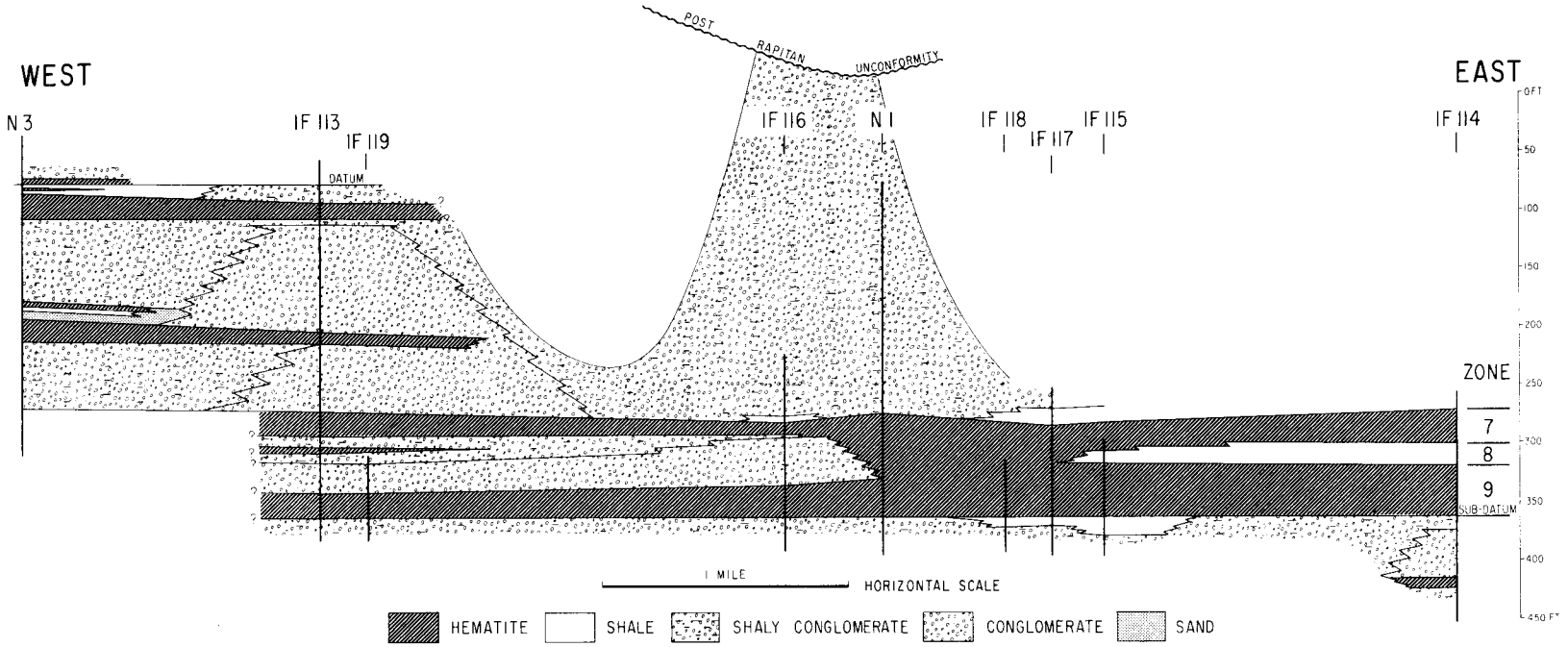
STRATIGRAPHIC CROSS SECTION No. 12 (EAST HALF)
CRANSWICK RIVER AREA



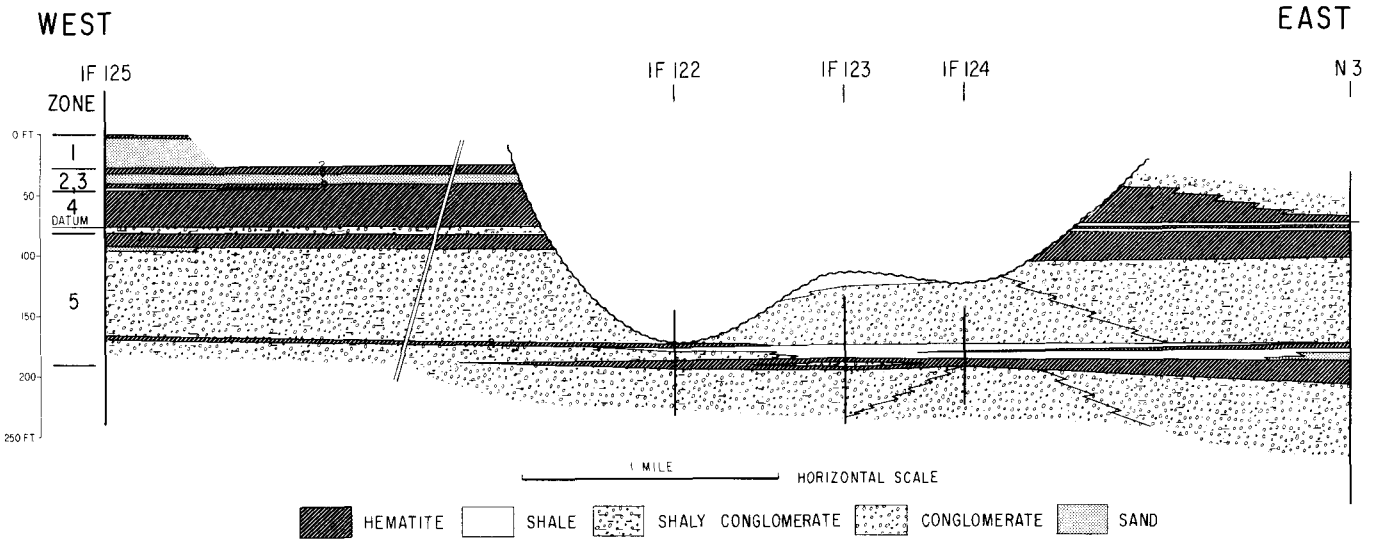
STRATIGRAPHIC CROSS SECTION No. 12 (WEST HALF)
CRANSWICK RIVER AREA



STRATIGRAPHIC CROSS SECTION No. 13 (EAST HALF)
CRANSWICK RIVER AREA



STRATIGRAPHIC CROSS SECTION No. 13 (WEST HALF)
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Sandstone is not a particularly abundant constituent of the iron-rich zone and is notable chiefly for the persistence of its beds, particularly in the Iron Creek block. One bed, ranging in thickness from five to ten feet, occurs in the lower part of the upper unit (Zone 4) and was used as the reference datum in the correlation of measured sections because of its widespread distribution. A second bed that occurs near the top of the zone (Zone 1) is nearly as persistent (Figure 2, page 29). These two sandstones have been designated the lower and upper marker sands respectively. Another rather widespread sandstone bed which occurs above zone one consists of grains of iron formation in a silty hematitic matrix and locally contains as much as 40% hematite. Small scour channels filled with sandstone have been observed in many parts of the map area, some exhibiting graded bedding.

Shale and siltstone are not volumetrically important in the section and usually form beds two feet or less thick and very limited in areal extent. Most such beds are sandy and many contain scattered small pebbles. Several thick beds of shale have been described but as these are silty and contain occasional pebbles and grade laterally into conglomerate, they may very well be pebble-poor exposures of normal shaly conglomerate beds.

Shaly conglomerate is by far the most abundant sedimentary type and forms beds within the iron-rich zone ranging in thickness from a few inches to sixty feet or more (Zones 6 to 8). Most of these beds are persistent, though some are highly variable in thickness and some pinch out entirely in rather short distances. The conglomerate unit in Zone 5 is one of the more unusual conglomerate horizons because over large areas it is a "normal" conglomerate with many pebbles rather than usual shaly conglomerate.

Five of the most significant stratigraphic features in the clastic units have been mapped in the Iron Creek block and the sedimentary trends shown by these features are indicated on the accompany map. These features show a basic northeast trend with a subsidiary northwest trend superimposed. These basic trends are also present in isopachs of the "ore" component of the iron formation.



Figure 1

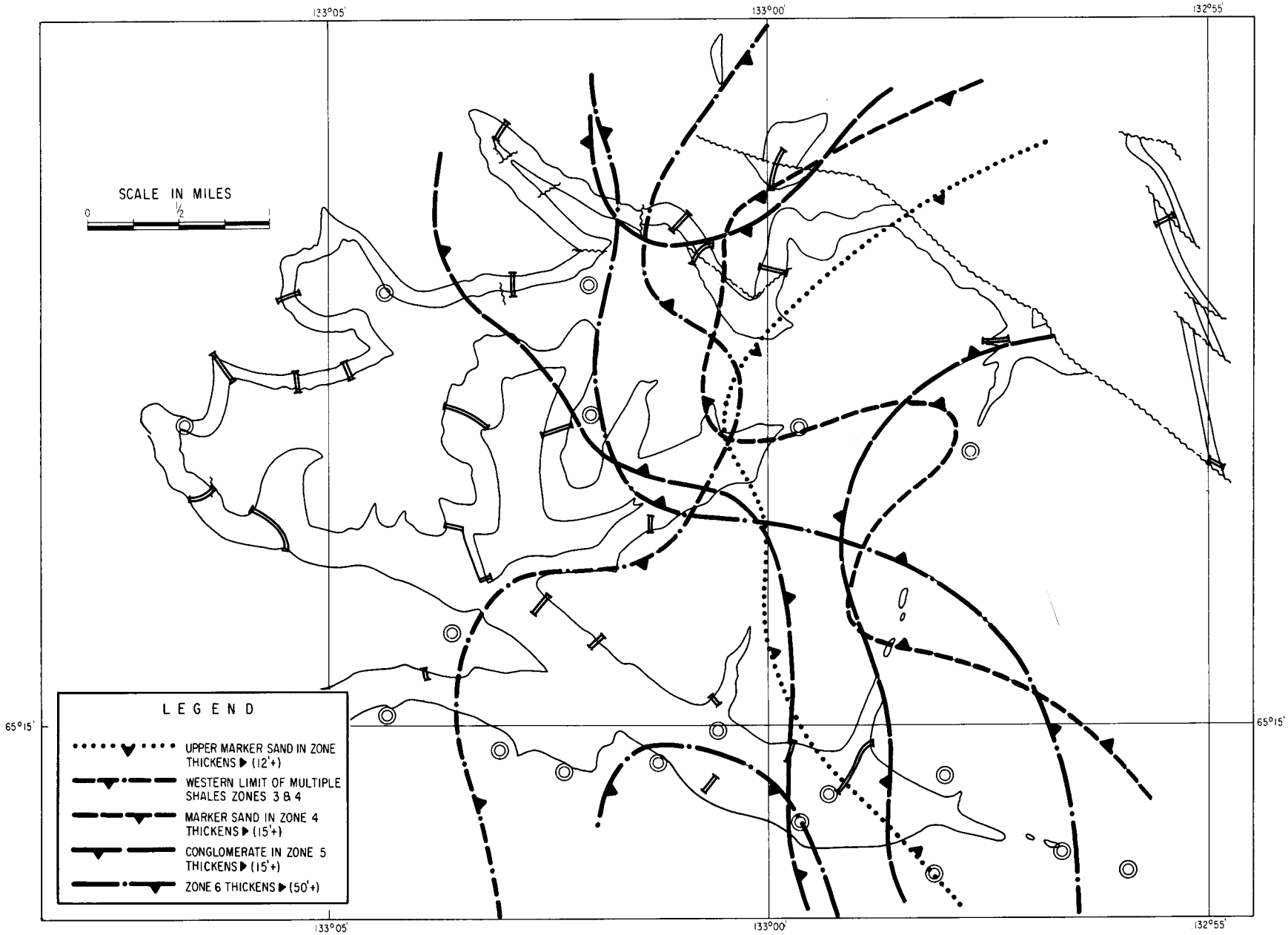
Iron formation in outcrop.
Exposure of Zones 1 to 7
(225') in Section IF-216-63



Figure 2

Upper marker sandstone in outcrop. Junction of
Iron Creek and Snake River in background.

IRON CREEK AREA - SEDIMENTARY TRENDS



Composition of the Iron Formation

Ore Component

The jasper-hematite type of iron formation constitutes a significant proportion of the lower 1000 feet of the shaly conglomerate. The greater part of the iron formation occurs in a restricted zone between 500 and 1000 feet above the lower unconformity, although iron formation bands of variable thickness have been observed in the lower 500 feet of conglomerate in several parts of the area. The iron-rich zone has been traced laterally for over thirty miles along an outcrop belt up to ten miles in width (see the geological map). The zone attains its maximum thickness in the area of Iron Creek, and generally thins toward both the east and the west, although the erosional removal of the iron formation to the north and its disappearance beneath younger strata to the south has prevented the determination of the absolute shape and dimensions of the iron-rich zone.

The hematite and jasper are closely associated with one another. The clastic sedimentary rocks form intercalated bands and lenses of variable dimensions. The following types of iron formation can be distinguished megascopically on the basis of the hematite-jasper textures.

(a) Nodular Iron Formation

This consists of 60% to 90% of dense very fine grained, steel-grey to maroon-tinted hematite containing small rounded or ovoid nodules of orange-red jasper. The jasper nodules are typically 1/8 to 1/4 inch in maximum dimension and may be scattered throughout the hematite or concentrated into bands (Figure 1 page 32). Frequently the nodules exhibit corroded margins and a hematite-rich oore, suggesting that there has been some replacement of jasper by hematite. The hematite is apparently structureless when it is steel-grey but frequently shows a faint lamination and streaky augen-like texture when maroon-tinted. The maroon tint is due to disseminated finely divided silica in the hematite, and becomes more pronounced as the amount of disseminated silica increases. The nodular iron formation frequently contains thin tubular plates of orange jasper aligned parallel with the bedding (Figure 2, page 32). Some exposures have been seen that suggest that these plates originate through the fragmentation of a continuous band of jasper (Figure 1, page 34).

(b) Banded Iron Formation

The banded iron formation consists of interbanded hematite and jasper. The bands may range from a fraction of an inch to several feet in thickness, they may be structureless or laminated, and they may be interbedded in any relative proportion (Figures 1 & 2, page 33). The jasper bands exhibit a range in colour from bright orange to dark maroon that reflects an increasing amount of disseminated hematite and the hematite bands range

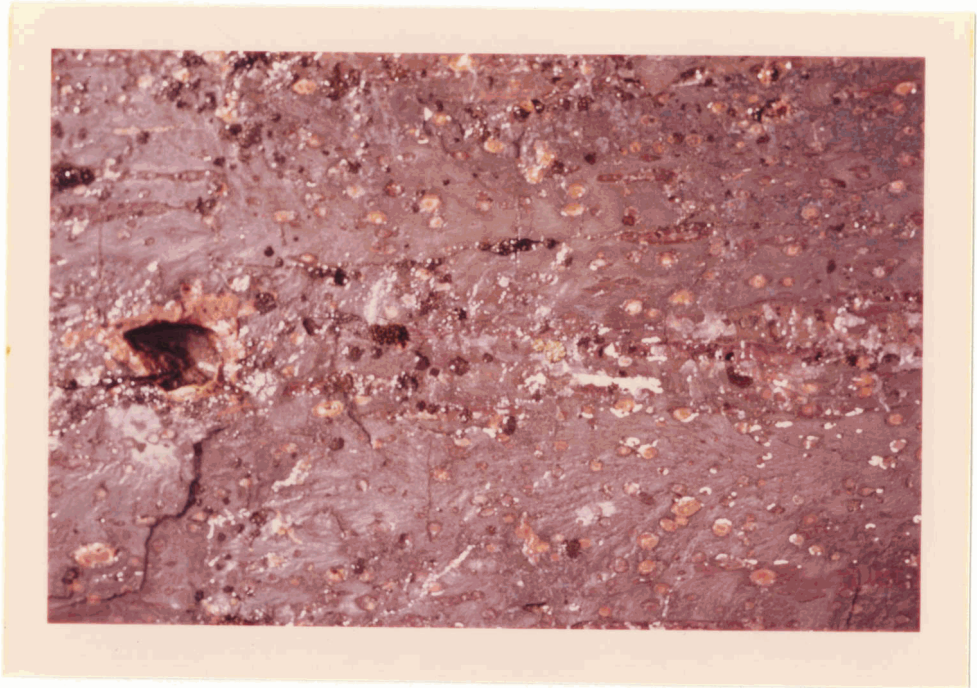


Figure 1

Nodular Iron Formation



Figure 2

Iron Formation with lenses of red jasper

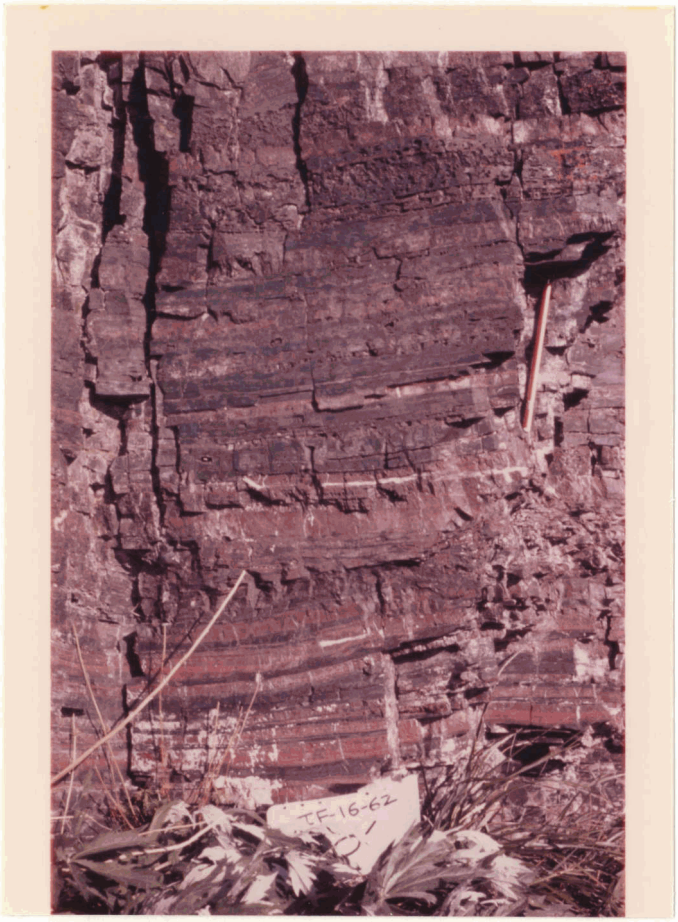


Figure 1

Banded Iron Formation with maroon jasper predominating



Figure 2

Banded Iron Formation with red jasper predominating



Figure 1

Nodular Iron Formation. Note the fragmented band of orange jasper below the painted mark.



Figure 2

Dislocated maroon jasper band. Note flowage structure in hematite defined by orientation or orange jasper plates.

in colour from steel grey to dark metallic maroon, depending on the amount of disseminated silica that they contain. The jasper bands tend to be thick where the hematite bands are thick and thin where the hematite bands are thin. The thick or thin bands occur in definite zones in the section. Commonly the jasper bands have been broken and tilted, especially where they constitute a minor proportion of the iron formation. In such cases planar features in the hematite characteristically show flowage structures around the broken ends of the jasper bands (Figure 2, page 34).

(c) Irregular Iron Formation

This type of iron formation is characterized by irregular masses and intergrowths of hematite and jasper. Either constituent may form the continuous phase, and complex flow-like structures are frequently observed (Figure 1, page 36). The hematite tends to contain a high proportion of disseminated silica and the chert tends to contain a high proportion of hematite, giving both a dark maroon cast. In some sections this type of iron formation has been traced laterally into coarse conglomerates containing pebbles of jasper and hematite.

The three basic types of iron formation may be very closely associated with one another, although the irregular type tends to be restricted to low grade zones. Interbedded units of banded and nodular iron formation are very common (Figure 2, page 36) and banded zones frequently contain scattered nodules (Figure 1, page 38).

The Clastic Component

Clastic members within the iron formation and the clastic intervals above and below it contain the same suite of lithologic and mineral constituents but the relative proportions of the individual constituents may differ in each unit. As well as forming relatively pure clastic members, clastic grains may also be scattered through some beds of predominantly nonclastic lithology. For example, pebbles and cobbles are common in carbonate layers within the iron formation, and the hematite or jasper at some horizons of the iron formation contains strings of isolated sand grains.

Conglomerate Fraction

The pebbles in the conglomerate members are composed chiefly of greenstone and light coloured carbonate and quartzite. Greenstone pebbles are more abundant than carbonate or quartzite pebbles in clastic members above the iron formation, while clastic members within and below the iron formation carry more carbonate and quartzite pebbles than greenstone pebbles. Most of the pebbles have angular outlines with rounded corners, but in some places the pebbles are a mixture of well rounded and angular shapes, the carbonate and quartzite pebbles being well rounded, and the greenstone pebbles angular. In one conglomerate member in the lower iron formation, fragments and oval masses of red jasper



Figure 1

Irregular Iron Formation. Note discordance in banding suggesting a "rolling up" of the jasper mass

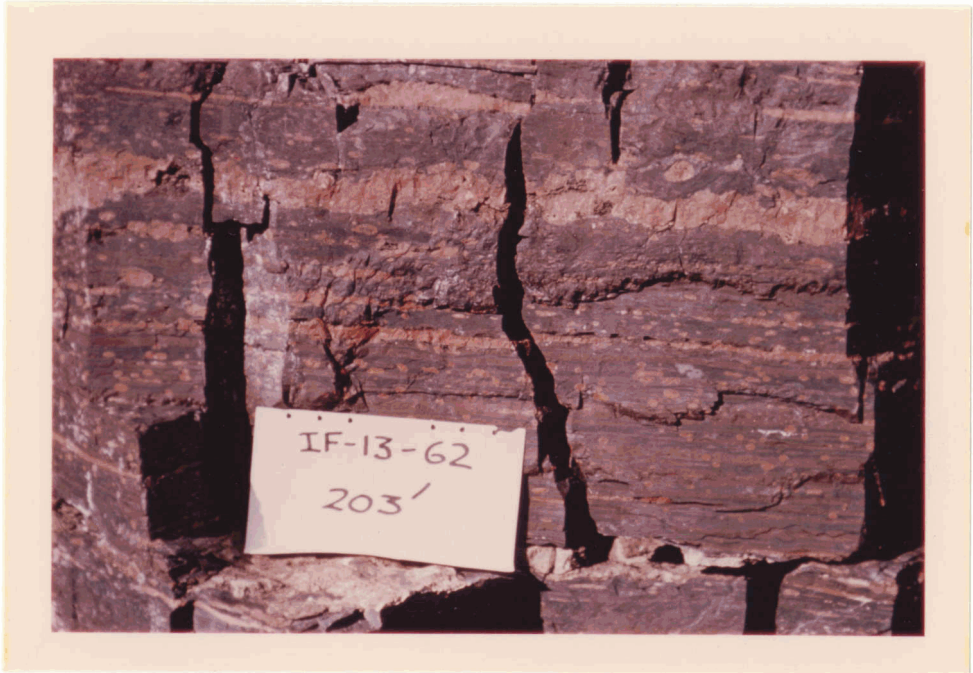


Figure 2

Associated nodular and banded Iron Formation

are very common. Some of the smaller jasper fragments are the cores of yellow to reddish pisolites which in general appearance resemble the jasper nodules in the hematite. They may represent an early stage of nodule formation which has been preserved in the conglomerate phase. Similar "proto nodules" have been seen in some of the conglomerate mudstones. Conglomerate zones up to at least 300 feet above the iron formation contain scattered fragments of red jasper (Figure 1, page 68).

The conglomerate rocks are usually composed of a few pebbles and cobbles scattered through a sandy mustone matrix which forms the bulk of the rock. Occasionally the conglomerate is composed mainly of pebbles, with only minor amounts of matrix which rests on a conglomeratic mudstone much richer in matrix. Pebble lithologies in the two phases show close similarities in some cases, but large differences in others, depending upon whether or not the clean conglomerate was derived by winnowing of the one underlying. Boulders in the conglomeratic members are occasionally quite large. One angular block if iron formation in the conglomerate member below the main sandstone marker has a computed weight of 2000 pounds (Figure 2, page 38) and a subangular block of greenstone in the post iron formation mudstone weighs about 800 pounds.

Members other than conglomerates also contain large boulders which usually occur singly. In one locality a boulder 10 inches high was deposited in a clastic layer 5 inches thick (Figure 2, page 40). In another example, a boulder 20 inches high is contained in a shale bed 8 inches thick in the iron formation; the boulder weighs about 700 pounds.

The boulders present in these thin partings in the iron formation comprise a very small part of the bed containing them, as in any one exposure there is usually only one boulder visible although that particular bed may be exposed for a length of 50 feet or more. The beds in which the boulders occur are generally not coarsely clastic and the boulders appear as incidental constituents. Within the iron formation, the height of the boulders is usually much greater than the thickness of the bed in which they occur. In a few examples a distinctive parting is absent altogether, and the boulder (cobble) is embedded in hematite. Evidently the bed or parting of shale or sandstone is not an essential part of the mechanism that has deposited the boulders.

Where the boulders are associated with partings, the time of deposition can be determined by tracing the bedding within the parting. In some cases the bulk of the parting post dates the deposition of the boulder, but in one example the boulder rests on the upper contact of the parting, so that it must have been brought to the site of deposition after the sediments of the parting had formed a bed. Consequently, transportation of the boulder by a mudflow composed of the materials in the parting seems to be ruled out. Apart from this the amount of sediment

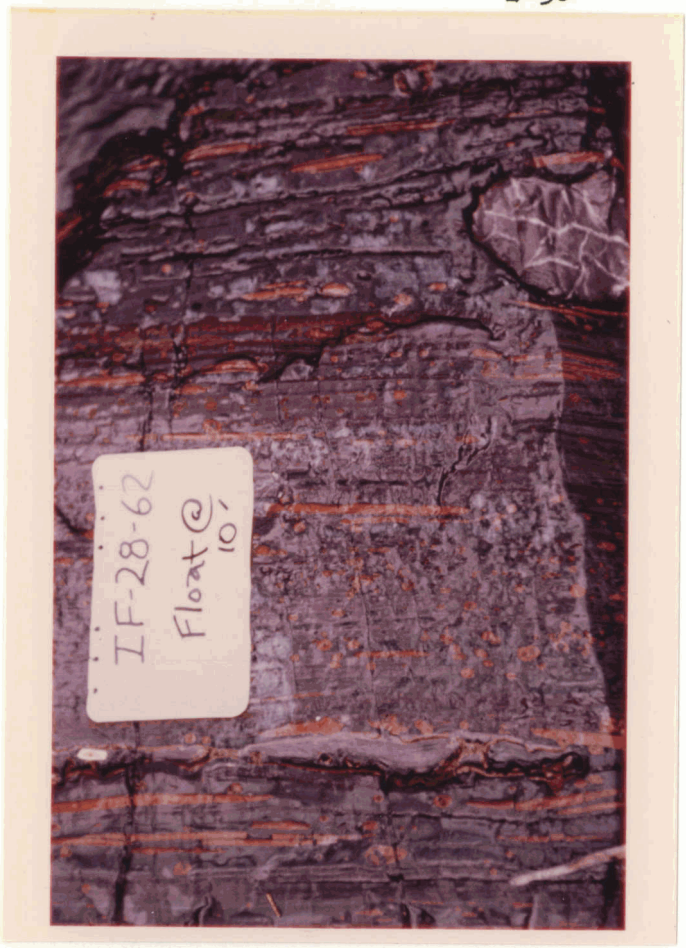


Figure 1

Bed of banded iron formation with scattered jasper nodules between two beds of nodular iron formation. Note limestone pebble imbedded in hematite in upper right corner.



Figure 2

Large angular block of jasper and hematite near top of conglomerate member in iron formation one-quarter mile north of D.D.H. Y-11-63.

in this parting and in the others seems to be insufficient to have formed a mudflow capable of carrying such large stones. The extreme example mentioned, in which there is no parting, is also evidence that mudflows were not the mechanism depositing the boulders. However, conglomeratic sandy mudstone members both within and outside the iron formation do have the matrix and chaotic fabric of mudflows.

Turbidity currents might have deposited the shaly or sandy partings associated with the isolated boulders as these materials are sorted and bedded. However, the boulders seem to require an additional explanation, since turbitity current deposits are noted for good sorting and grading, and any boulders carried by such currents would be expected to form sorted boulder beds. It is difficult to find an alternative to the ice rafting hypothesis that will explain the presence of boulders in nonclastic iron ore as well as in sediments that otherwise are fairly well sorted.

A muddy conglomerate member in the iron formation includes large masses of red jasper up to several feet long and a foot thick, some of which resemble broken halves of large concretions, one end of the masses being oval, and the other end being square. Two plastically folded masses of jasper have also been seen in the conglomerate. The folded part of one mass extends into the surrounding matrix as a slender salient that could not have survived transportation, showing that the folding has taken place within the conglomerate while the rock was still fairly soft. Mass movement of the conglomeratic material as a stony mudflow would explain the folding and also the vertical orientation of some elongate fragments. The same movement would also cause erosion of the underlying jasper beds, and bring about the inclusion of large jasper concretions and fragments of unconsolidated jasper beds. Turbidity currents might have arisen from the stony mudflows that formed the conglomeratic mudstone thereby depositing beds of shale and sorted sandstone beyond the margins of the mudstone deposits. One muddy conglomerate member in the lower-middle part of the iron formation thins out and is replaced laterally by beds of this type, implying that such turbidity currents did exist.

At one locality in the middle of a conglomerate unit there is a lens of banded jasper and hematite which has filled a depression that existed during conglomerate deposition (Figure 1, page 40). The lens has a flat upper surface that is nearly conformable with the banding and that is overlain by conglomerate. The presence of this lens in the conglomerate clearly demonstrates that the iron formation and the conglomerate were deposited under the same conditions. The difference seems to lie in the mechanism of deposition, the iron formation being due to continuing precipitation in quiet water, whereas the conglomerate is the product of catastrophic mudflows that invaded the area of precipitation at irregular intervals.



Figure 1

Wedge shaped trough filling of banded hematite and jasper in middle of conglomerate member in iron formation. Location between IF-128-63 and IF-209-63.



Figure 2

Rounded boulder 10" x 16" of flat pebble carbonate conglomerate in 5 inch bed of sandstone composed of shale flakes. The boulder has squeezed the underlying iron formation outward into bordering bulges.

Clastic materials in the iron formation and adjacent clastic beds are not deeply weathered. Except for the volcanics, which are changed to greenstones, most of the rocks are only slightly altered. On this account, a lateritic origin does not seem reasonable for the iron formation. Some crystalline carbonate pebbles in the conglomeratic mudstones have been altered to chlorite in varying degrees from the border inward, and when completely altered cannot be easily distinguished from greenstones (Figure 1, page 68). The change is probably post depositional since the chloritic rims are of even thickness, showing no truncation due to abraision. The conglomeratic mudstones also contain scattered masses of chalcopyrite having the shapes of small pebbles and coarse sand grains which are evidently due to replacement of certain favourable lithologic rock types. Chalcopyrite is also present as small patches in the jasper-hematite of the iron formation.

Sand Fraction

The sand size clastics contain all of the lithologic components of the conglomerates although the proportions are different as well as large amounts of grains whose lithologies are uncommon as pebbles in the conglomerates. The most common sand size grains are lumps and wispy fragments of red mudstone, followed in order of abundance by grains of harder red or green argillite. Quartz grains are also common, they are well rounded when coarse, but are angular when finer. Some sandstones contain abundant grains of light coloured crystalline carbonate and greenstone.

Certain thin sandy zones in the upper iron formation are composed largely of blackish green chloritized volcanic fragments and chloritized shards (Figure 1, page 42). One of these tuff zones is a local marker that lies 3-25 feet below the base of the upper sandstone marker. Its thickness is commonly only a few inches, but it varies rapidly over short distances because of irregularities in the surface on which it rests. In one place the thickness increases from 1 foot to 4 feet in a distance of 200 feet.

About 30 feet above the upper sandstone marker of the iron formation there is a 5 to 10 foot member of coarse sand size hematitic rock composed of wispy, compacted grains of jasper in a hematite matrix (Figure 2, page 42). Apparently the grains were not fully lithified when deposited. Similar but thinner members have been seen at higher and lower stratigraphic levels. The grains in these sandstones were derived from an unlithified source rock resembling the iron formation in composition. The presence of these sandstones in the iron formation and in the post iron formation interval indicate that the Snake River iron formation was exposed to erosion or that some other unknown iron formation was being eroded. Evidence favouring the first alternative is seen in the erosional truncation of the iron formation which has taken place

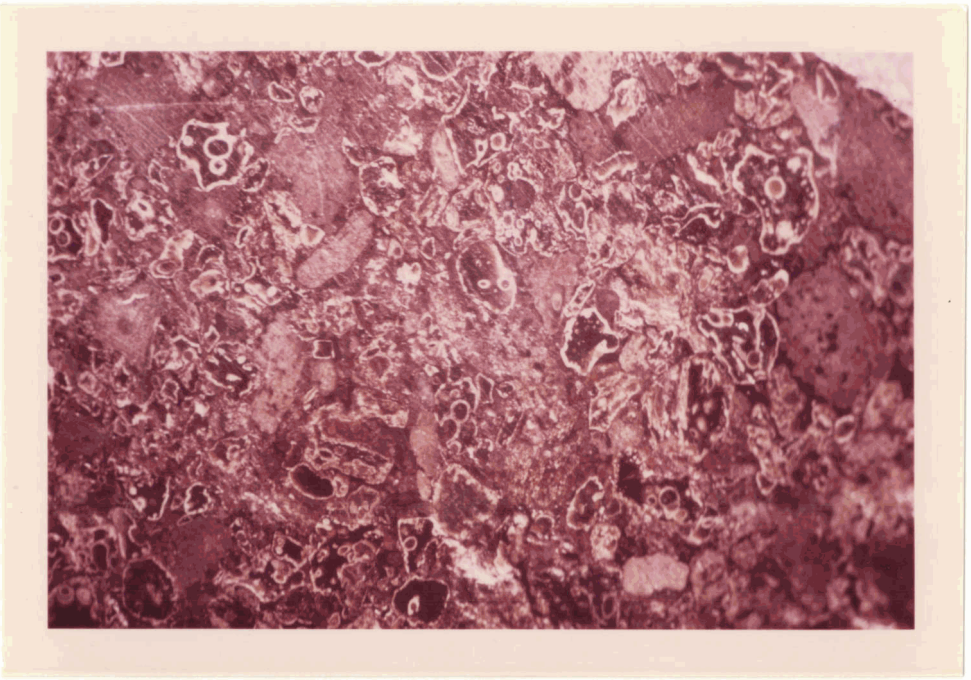


Figure 1

Polished section photomicrograph of volcanic tuff in iron formation near top. The bubbly glass shards have been altered to dark green chlorite; the greyish and brownish oval grains are volcanic (?) mudballs. Width of field 9.6 mm.

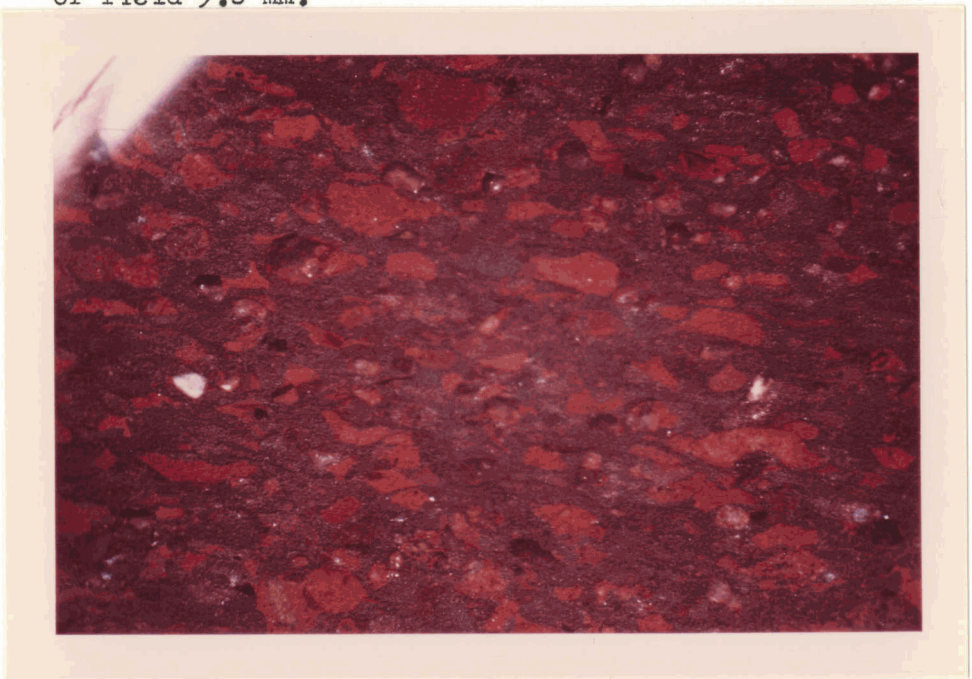


Figure 2

Polished section photomicrograph of jasper-hematite sandstone about 30 feet above upper sandstone marker. Note scattered clear quartz grains. Length of field 14.5 mm.

in the southwest and northeast parts of the outcrop area, where only the lower part of the formation remains. It is overlain by conglomeratic sediments of the post iron formation interval. With some local exceptions the jasper-hematite sandstone is present in the central part of the area of iron formation but in a few places along the south and eastern borders of the area of outcrop it is absent.

Mud Fraction

The matrix of the sandstones and conglomerates consist of red mudstone in variable amounts, from a trace to over 50% (Figure 1, page 68). In some rocks containing clastic grains of mudstone as well as matrix, it is difficult to estimate the relative proportions of grains and matrix. On this account, it is likely that the percentage of matrix is somewhat lower than it appears to be. The mudstone matrix is more or less ferruginous, ranging from hematite-rich submetallic material to brown rock matter relatively low in iron. The iron formation and associated beds also include zones that can be called shale or shaly hematite, and beds of more or less argillaceous carbonate.

Carbonate Component

Thin beds and partings of buff and reddish argillaceous carbonate have been seen throughout the iron formation but are absent from the clastic intervals preceding and following it. The carbonates are commonly dolomitic, and often contain large amounts of fine clay-like matter which cannot be estimated unless an acid residue test is made. Consequently, some of the rocks classed as carbonate in the field are probably dolomitic mudstone.

The carbonate beds are from 1 mm. to about 2 feet thick and have sharp undulating contacts with beds above and below. The carbonate is slightly more resistant to compaction than the surrounding iron formation, as indicated by compaction features, and by buckling and fracturing of the carbonate accompanied by flowage of the surrounding iron formation (Figures C & D, page 65). Figure B illustrates load casts at the base of a carbonate bed.

Abundant carbonate is present as matrix in parts of the conglomerate member in the lower middle iron formation. Also present are carbonate pisolites that in some cases have formed around angular cores of red jasper and green lava (volcanic glass?). The pisolitic coatings are absent from fragments and pebbles of other rock types in the conglomerate, and therefore it is unlikely that the coatings were formed at the site of deposition.

Carbonate nodules are occasionally present in the hematite. They are composed of light yellowish fine grained dolomite which is unlike the more common patches of sparry replacement carbonate. In some occurrences the nodules are flanked by drape structures in the hematite, and are therefore primary or early diagenetic.

Ore and Waste Isopachs

Isopach maps of the ore and waste constituents were prepared for each of the divisions recognized within the main ore zone (Zones 1 to 7) of the Iron Creek area. These were prepared partially as a means of studying the detail geology of the ore deposit and partially for the calculation of grades and reserves. The dual usage made it necessary to disregard minor constituents. Waste horizons (-35% Fe) less than five feet in thickness have been lumped with ore (+35% Fe) and vice versa. This is too coarse a breakdown for geological purposes and too fine for tonnage calculation but a reasonable compromise as the first approximation for both.

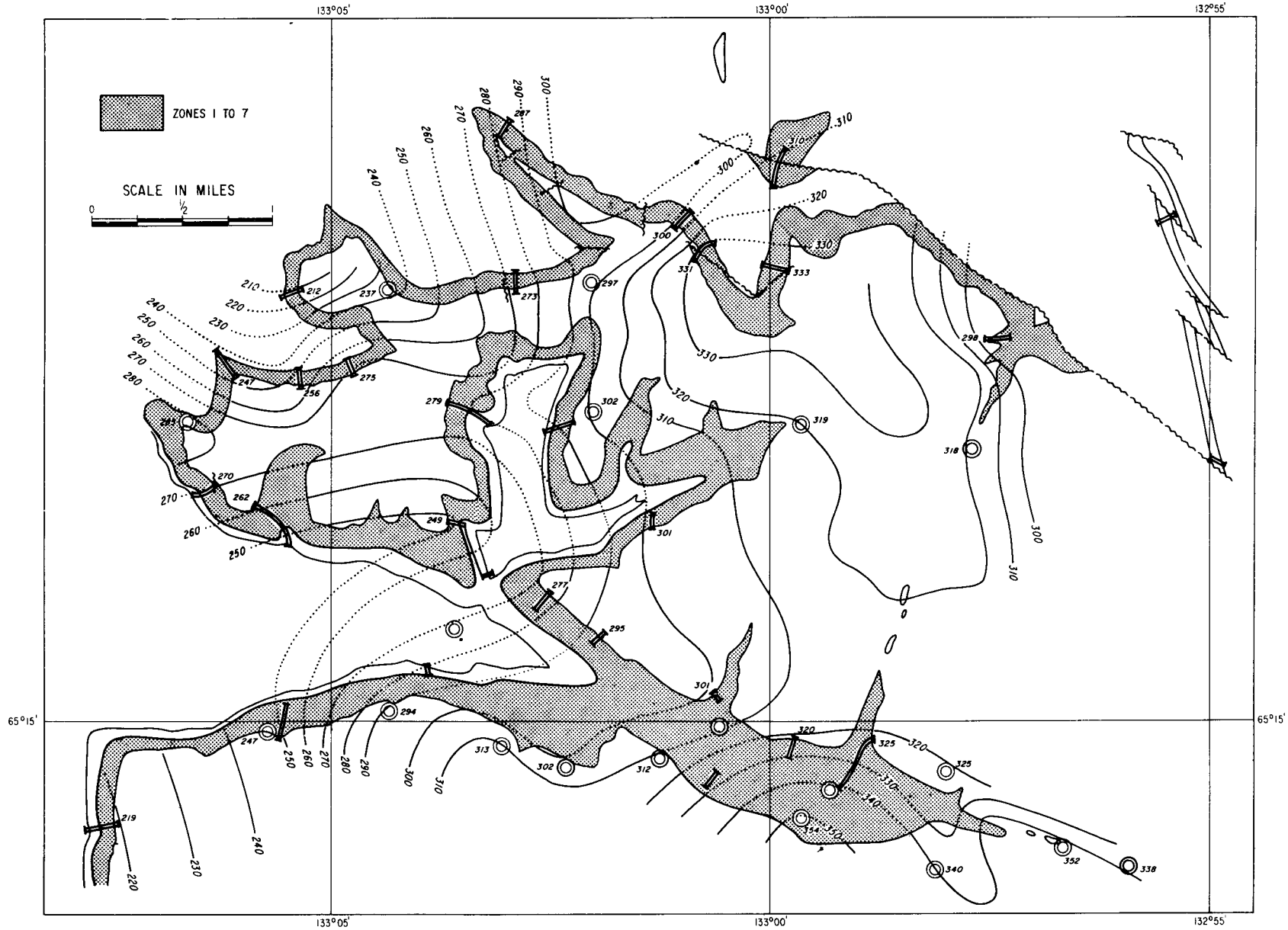
The total isopach map for zones one to seven shows that the thickness of the iron formation is fairly constant throughout the Iron Creek area. This constancy is not as evident in the isopach of the ore and the waste constituents which each display greater variations than does the overall isopach. The isopach of the internal waste which is particularly variable is thinnest in the valley of Iron Creek and thickest in the northeast. This is just the opposite of the thickness distribution shown by the potential ore isopach map. The inverse isopach relationship between ore and waste produces a fairly uniform overall thickness.

Total isopach, internal waste and potential ore isopachs have been constructed for each of ore zones one to seven. Zone 9 was not studied because the stratigraphic control is not adequate. The total isopachs for individual zones show thickness trends just as do the ore and waste isopach maps. It was hoped that by comparing the three isopach maps one could determine which was the positive element and which the passive element in establishing isopach pattern. The only criterion one can use is the degree of correspondence between isopach patterns. One would expect a closer correspondence between the dominant constituent and the overall pattern than between the passive constituent and the overall pattern.

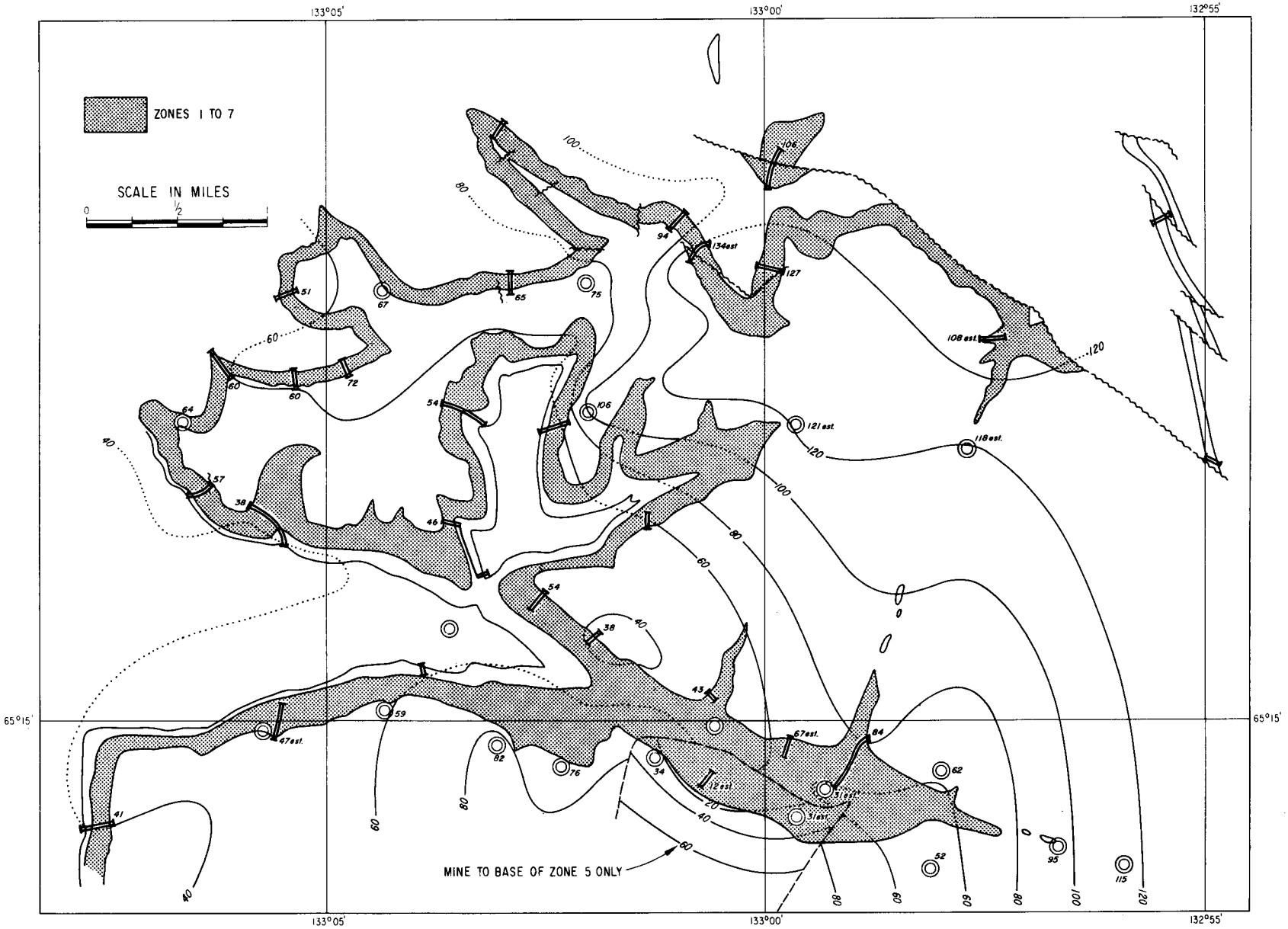
The isopach maps of the internal waste show two directional elements - a north-northwest trend and a northeast trend. These same trends appear in the comparable ore isopach maps. There is usually, but not invariably, compensation between the two components. When compensation is incomplete then distinct trends appear in the total isopach for that particular horizon. The overall isopach is fairly constant, because local irregularities within any one zone are ironed out by compensating thickness changes in successive horizons. From study of the isopach maps alone it is not possible to say whether it is the deposition of the waste or the deposition of the iron component which is the positive causative element.

Elsewhere in the geological discussions evidence is presented which suggests that much of the clastic waste material was transported by means of a mud flow type of mechanism which implies a linear distribution of sediment. Also evidence is presented which suggests that the iron formation was quite mobile, perhaps even in a semi-gelatinous form for some time after deposition. This means that

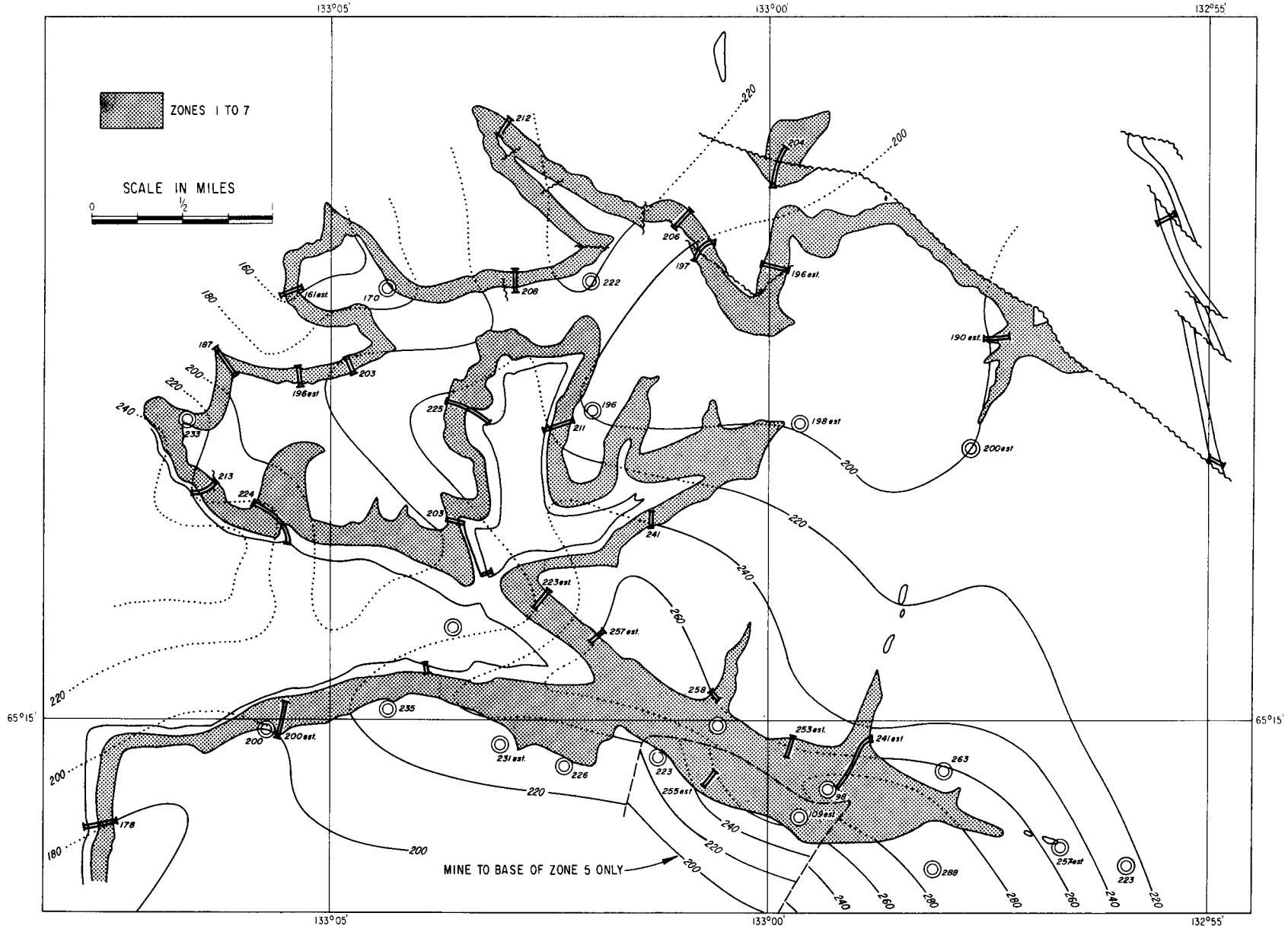
IRON CREEK AREA - TOTAL ISOPACH, ZONES 1-7



IRON CREEK AREA - ISOPACH OF INTERNAL WASTE, ZONES 1-7



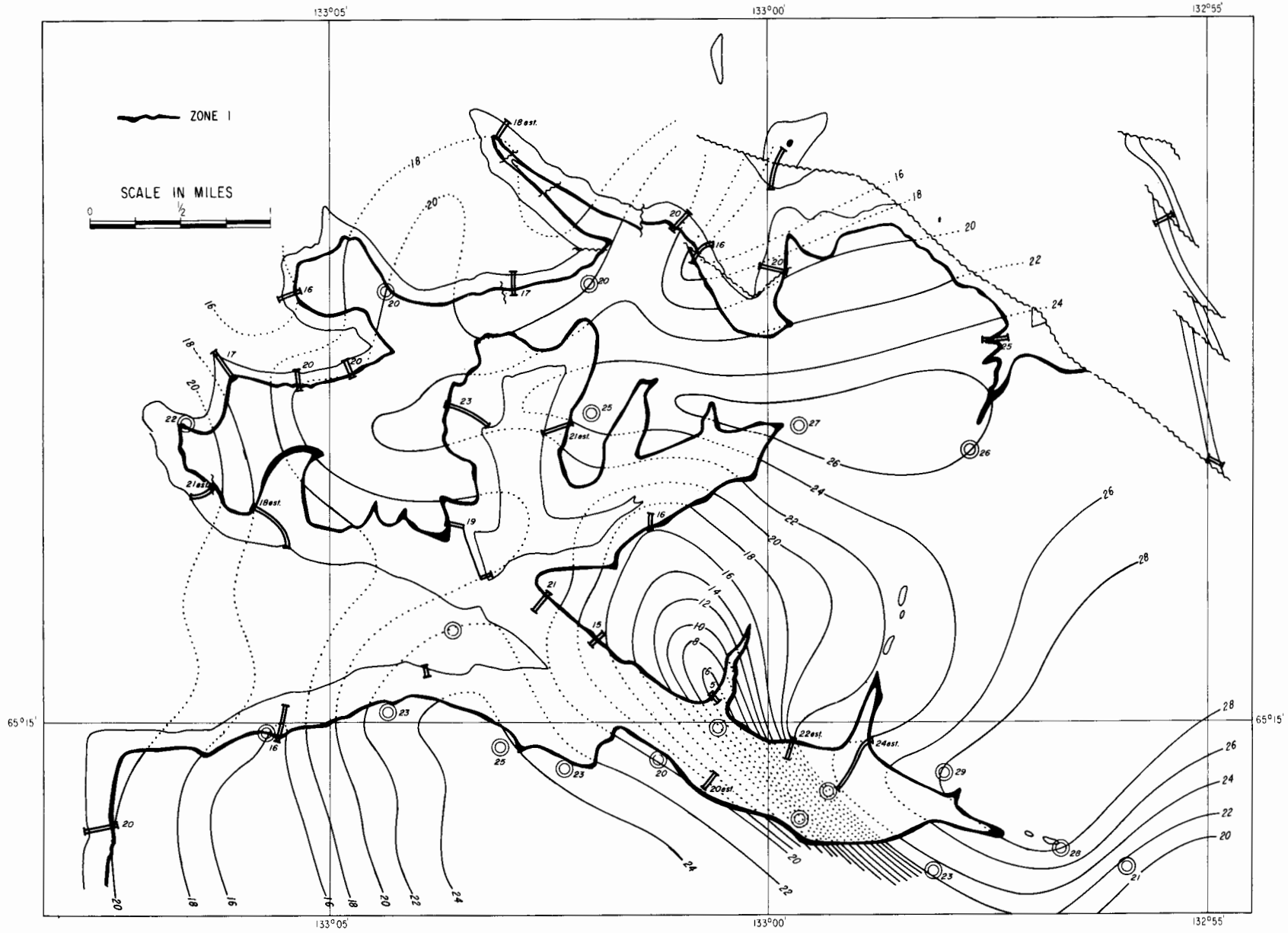
IRON CREEK AREA - ISOPACH OF POTENTIAL ORE, ZONES 1-7



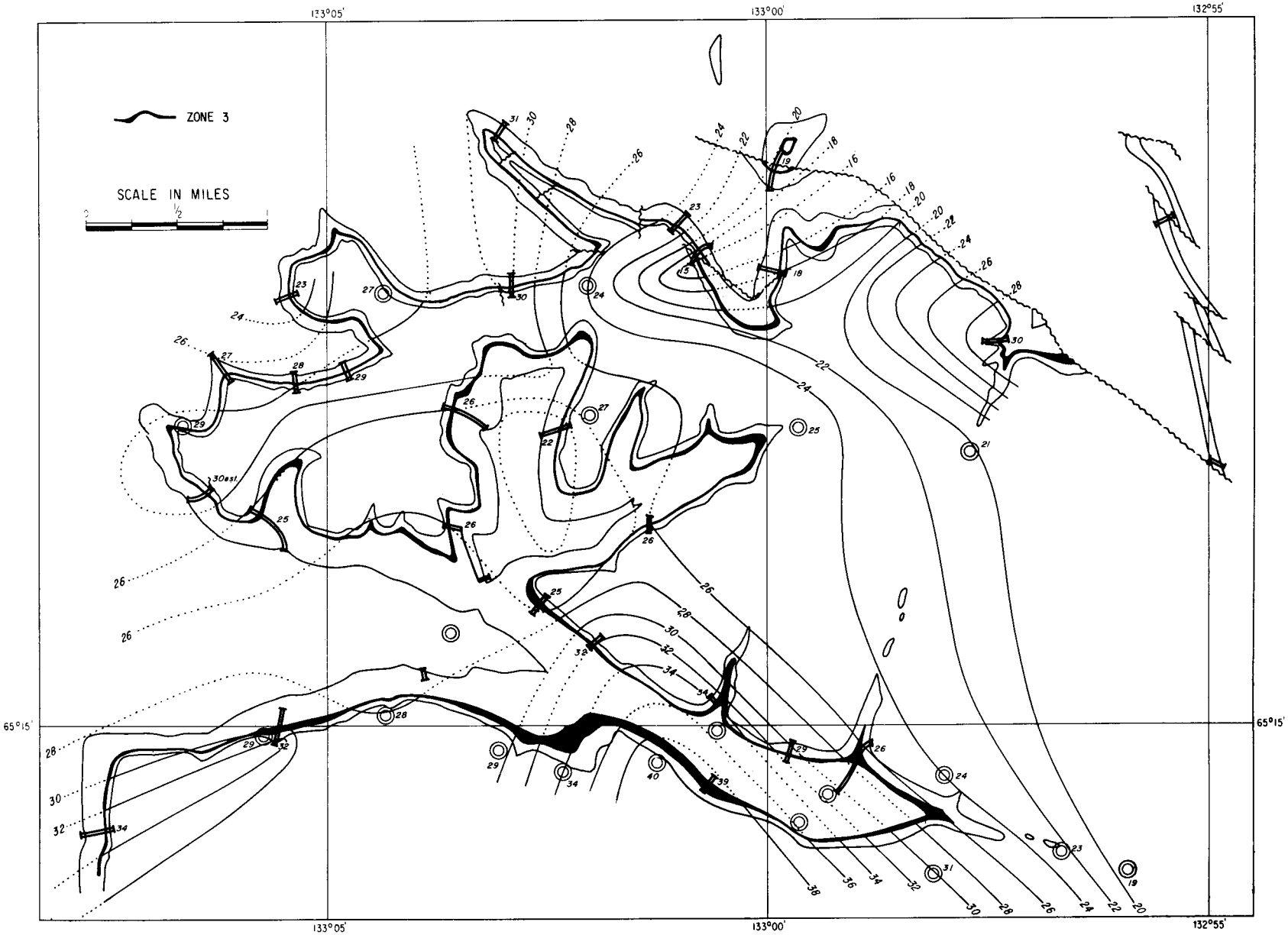
differential compaction would affect the iron formation more than the clastics. These considerations suggest that the clastics were the dominant feature in developing the depositional patterns displayed by the isopachs but the isopachs themselves are equivocal.

It is possible that by studying the isopachs in conjunction with the stratigraphic sections one might be able to formulate some valid opinion as to the sequence of deposition. Moreover, there is a wealth of unstudied detail available from the cores and the sections which would permit detailed correlations within the iron formation that could be used to study differential compaction. There are also good cliff exposures in the field where ideas developed by the foregoing methods could be tested so it is probable that the question as to which element is dominant could be solved if there were sufficient economic incentive to justify the work.

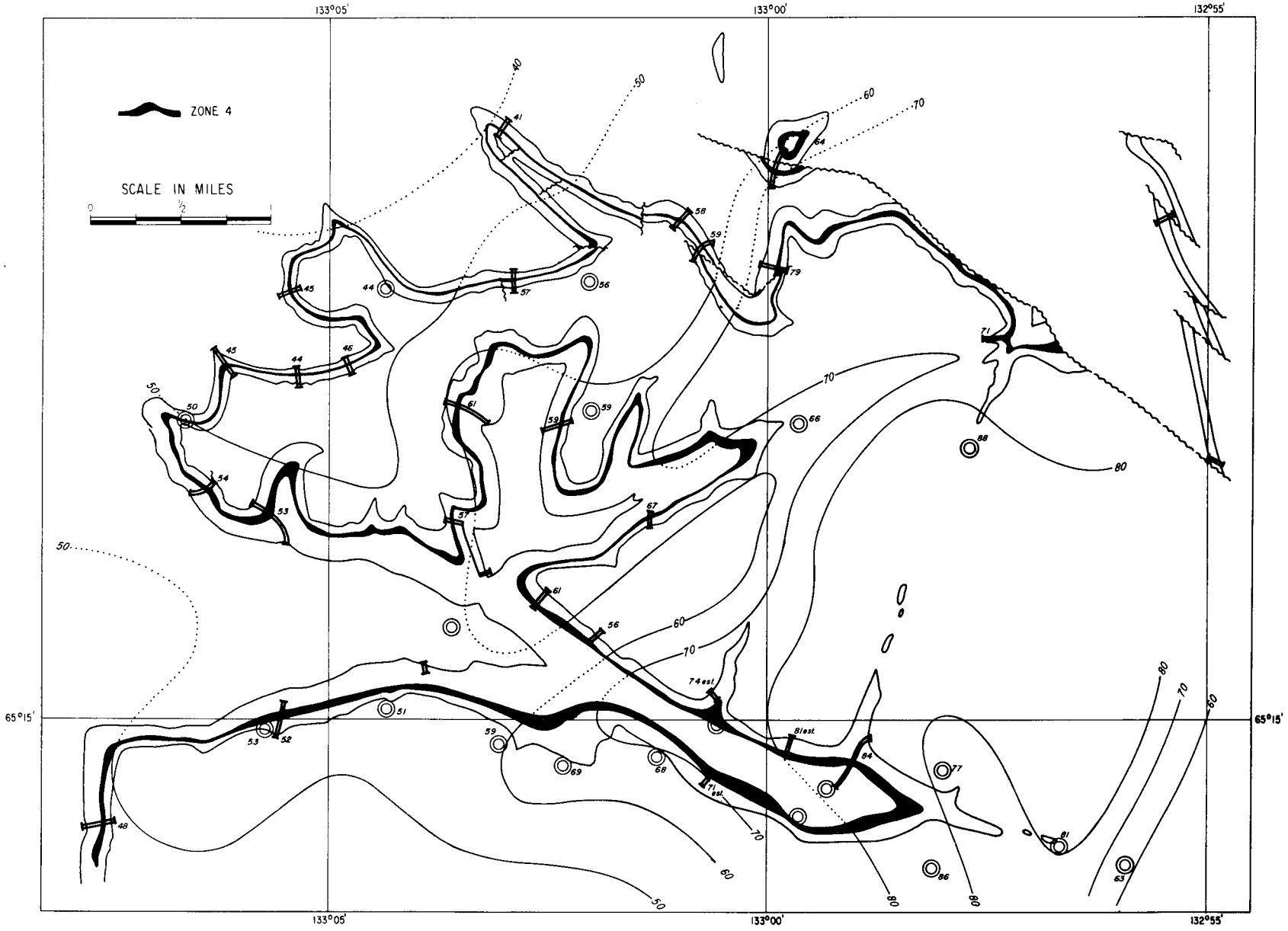
IRON CREEK AREA - TOTAL ISOPACH, ZONE I



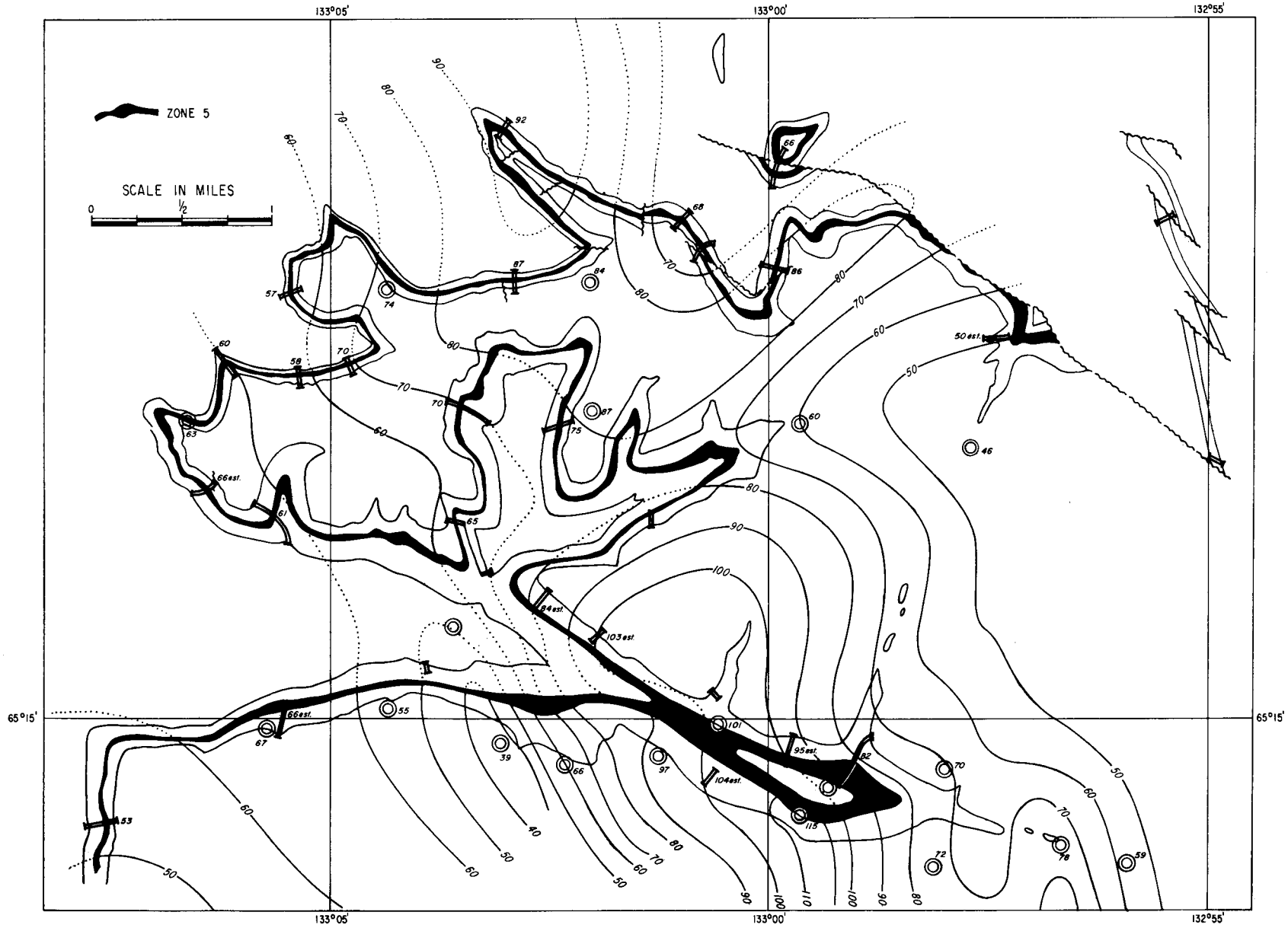
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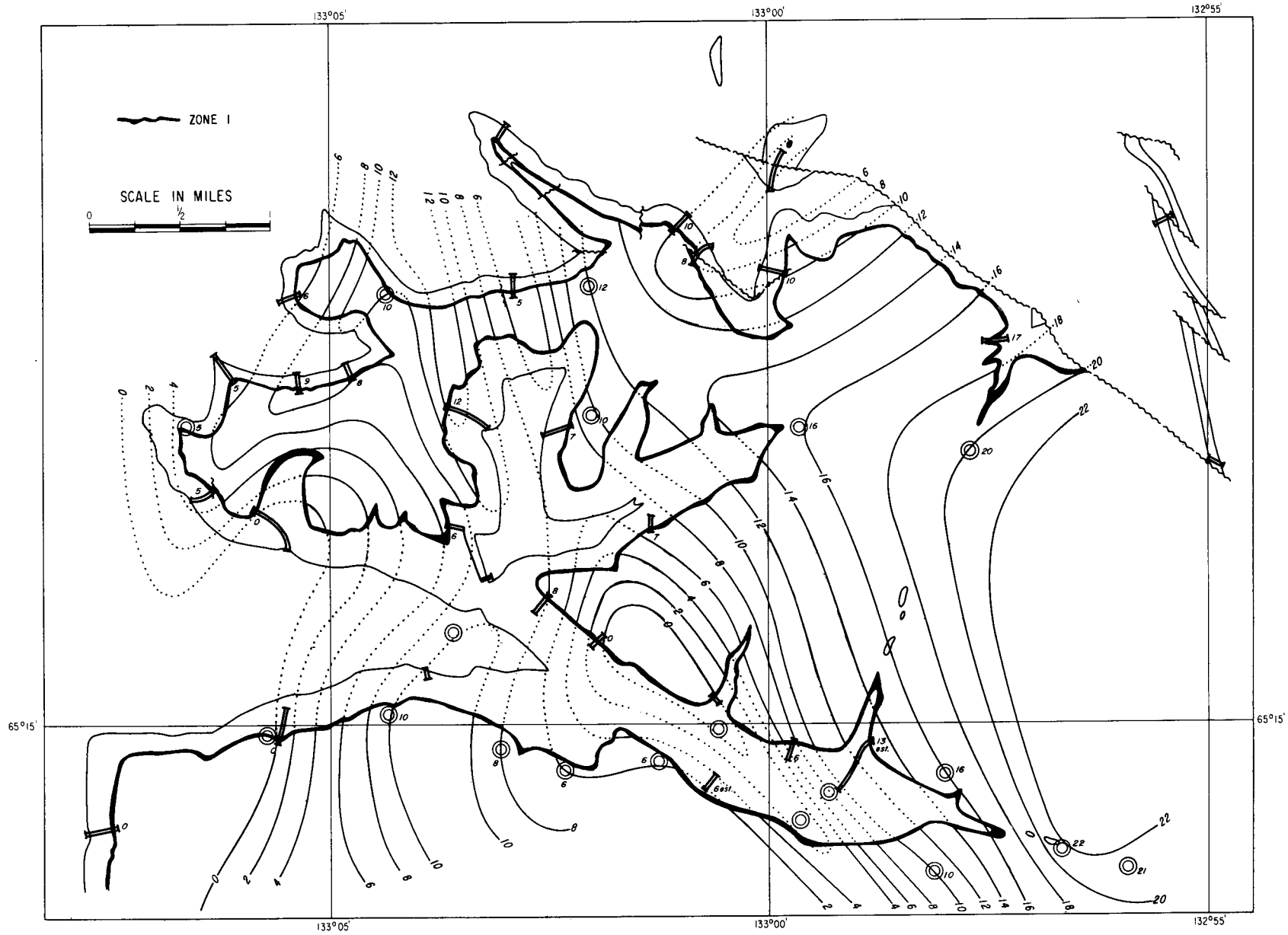
IRON CREEK AREA - TOTAL ISOPACH, ZONE 4



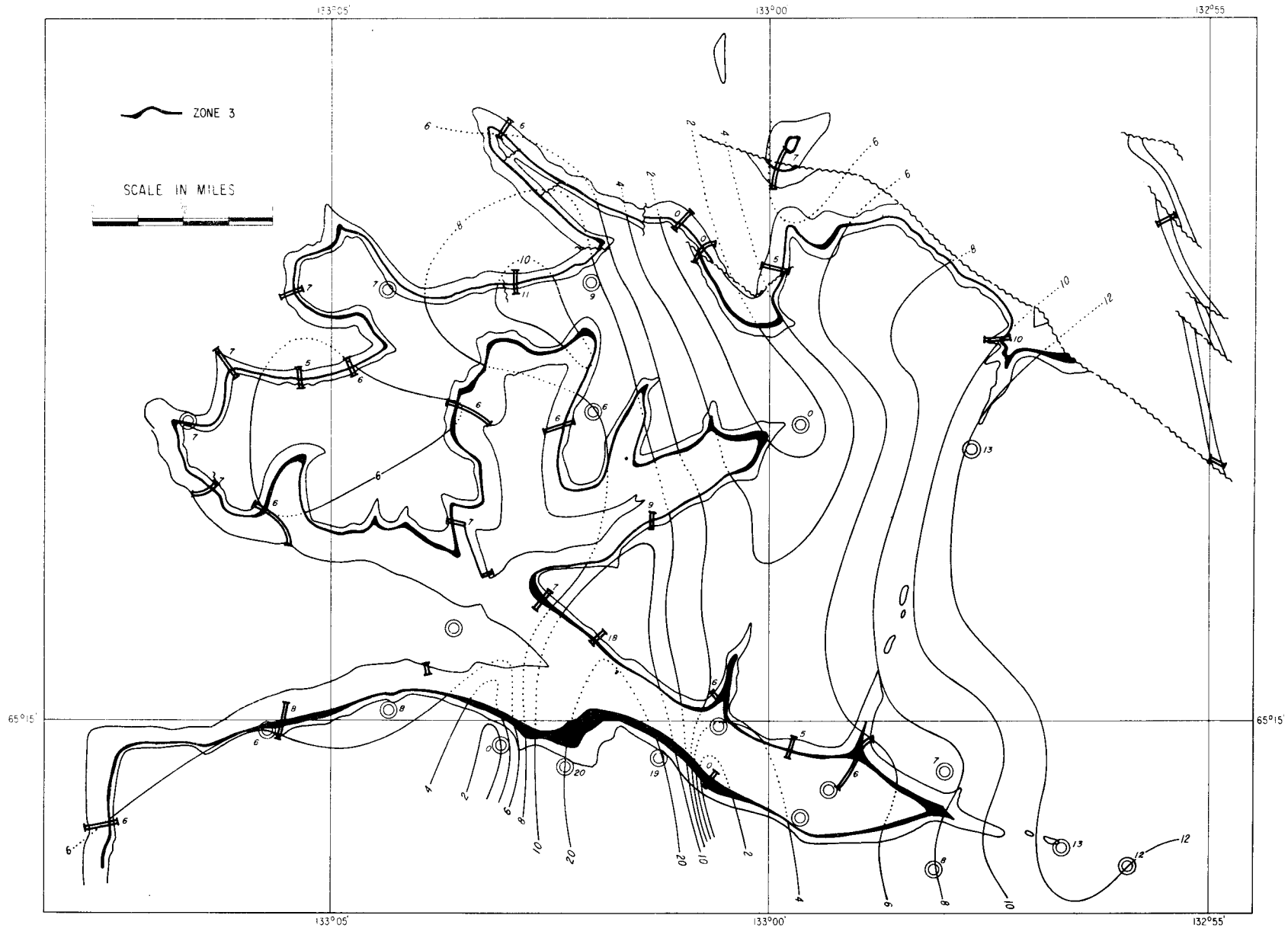
IRON CREEK AREA - TOTAL ISOPACH, ZONE 5



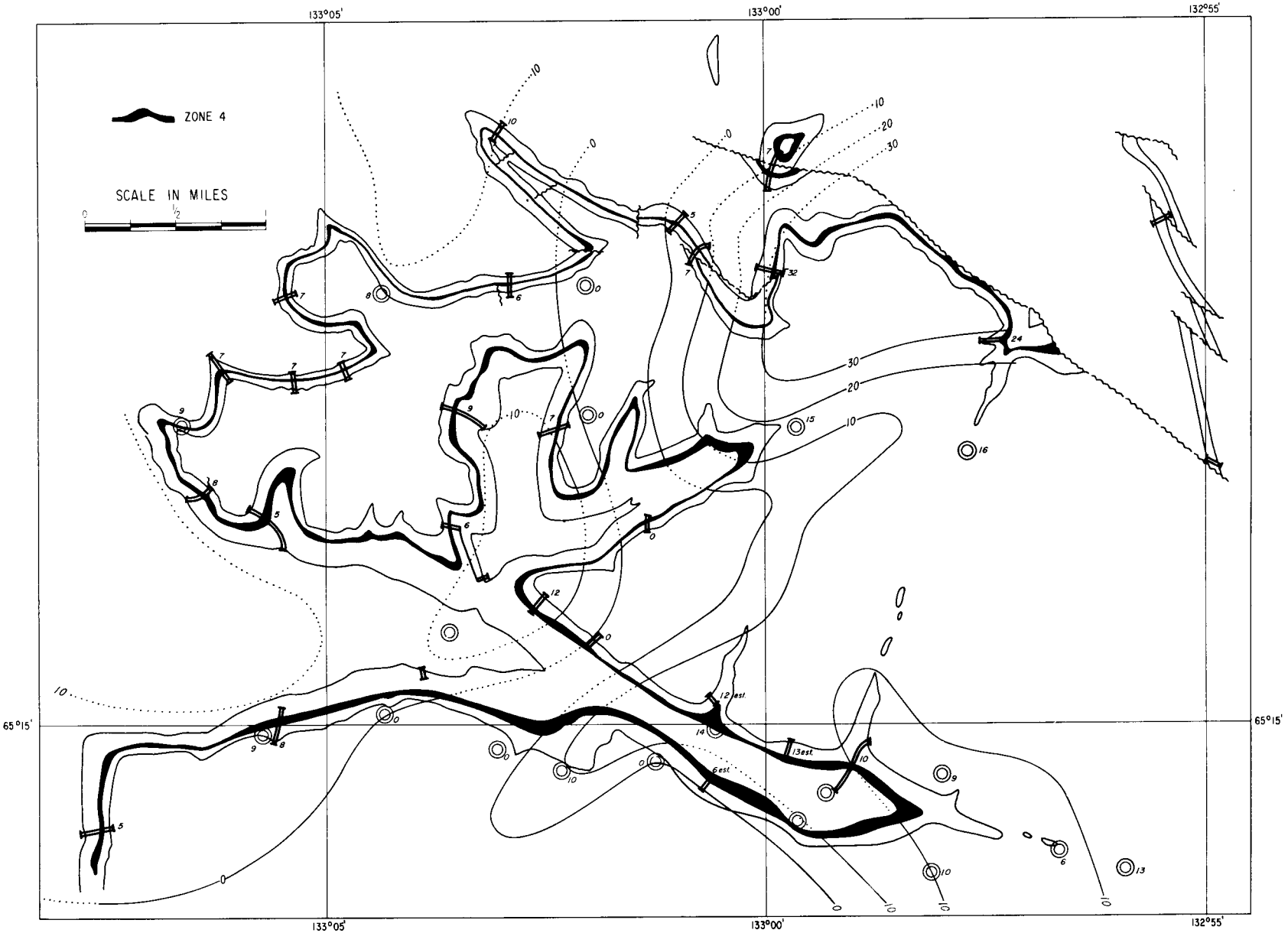
IRON CREEK AREA - ISOPACH OF INTERNAL WASTE, ZONE I



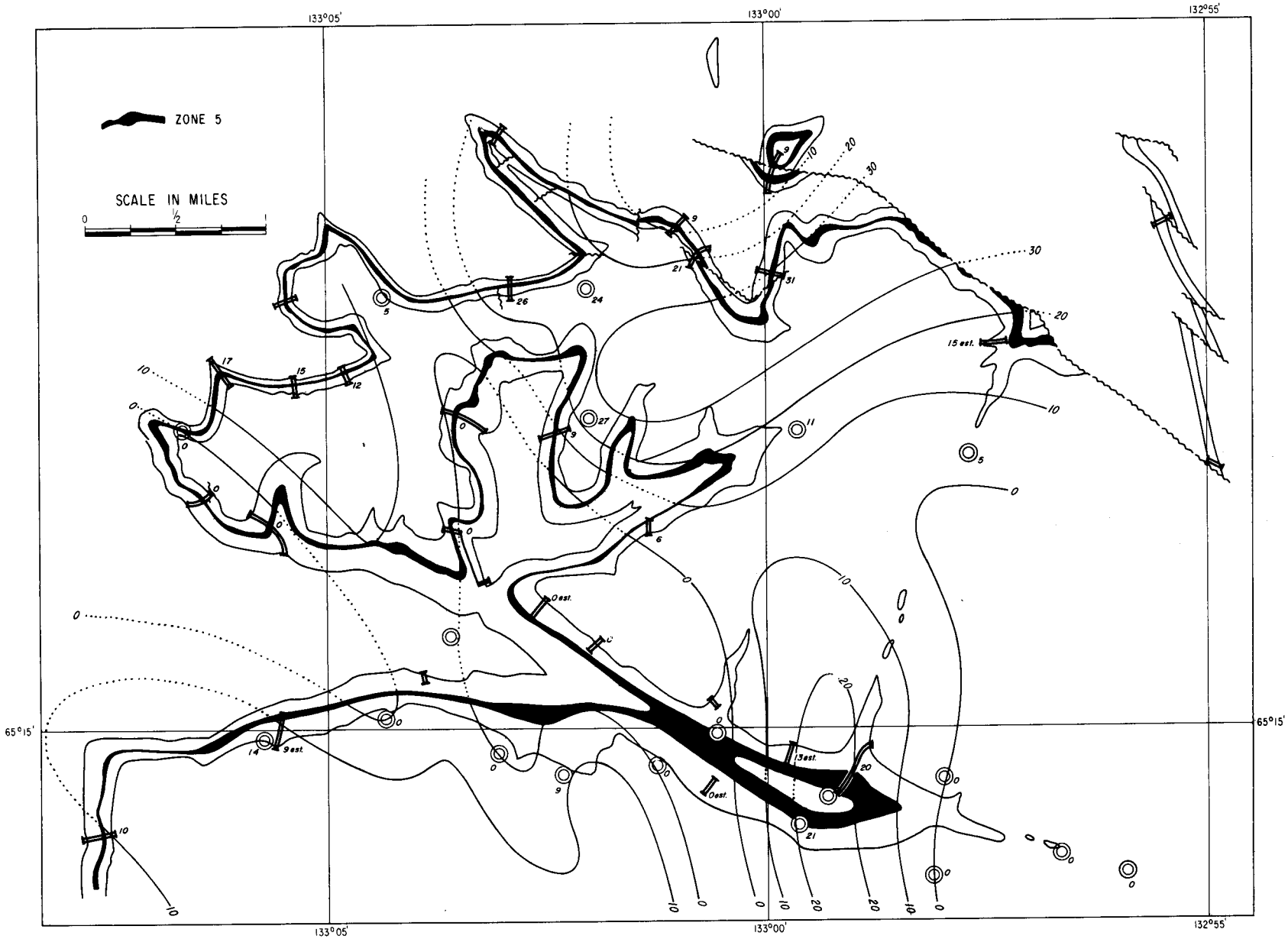
IRON CREEK AREA - ISOPACH OF INTERNAL WASTE, ZONE 3



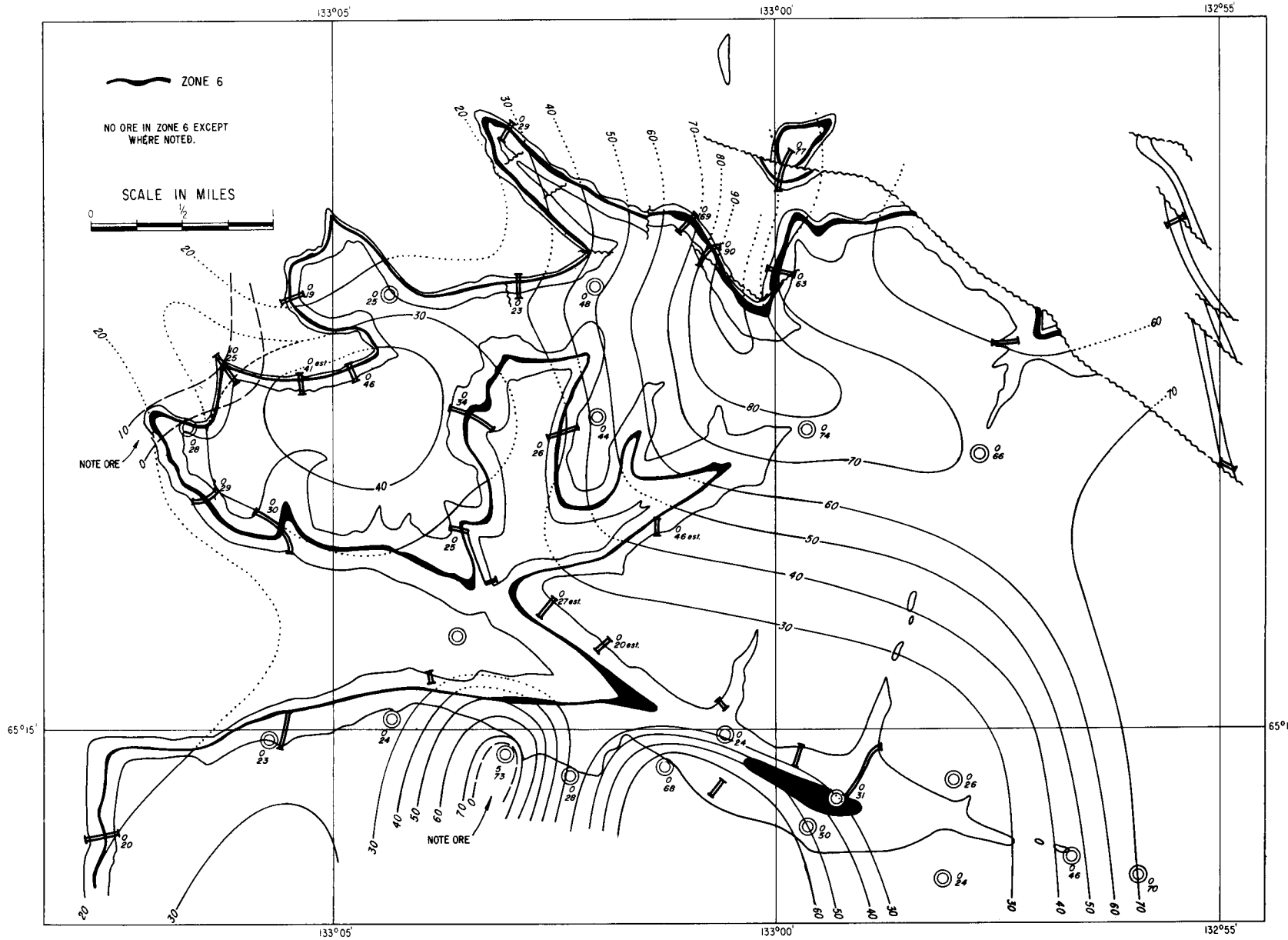
IRON CREEK AREA - ISOPACH OF INTERNAL WASTE, ZONE 4



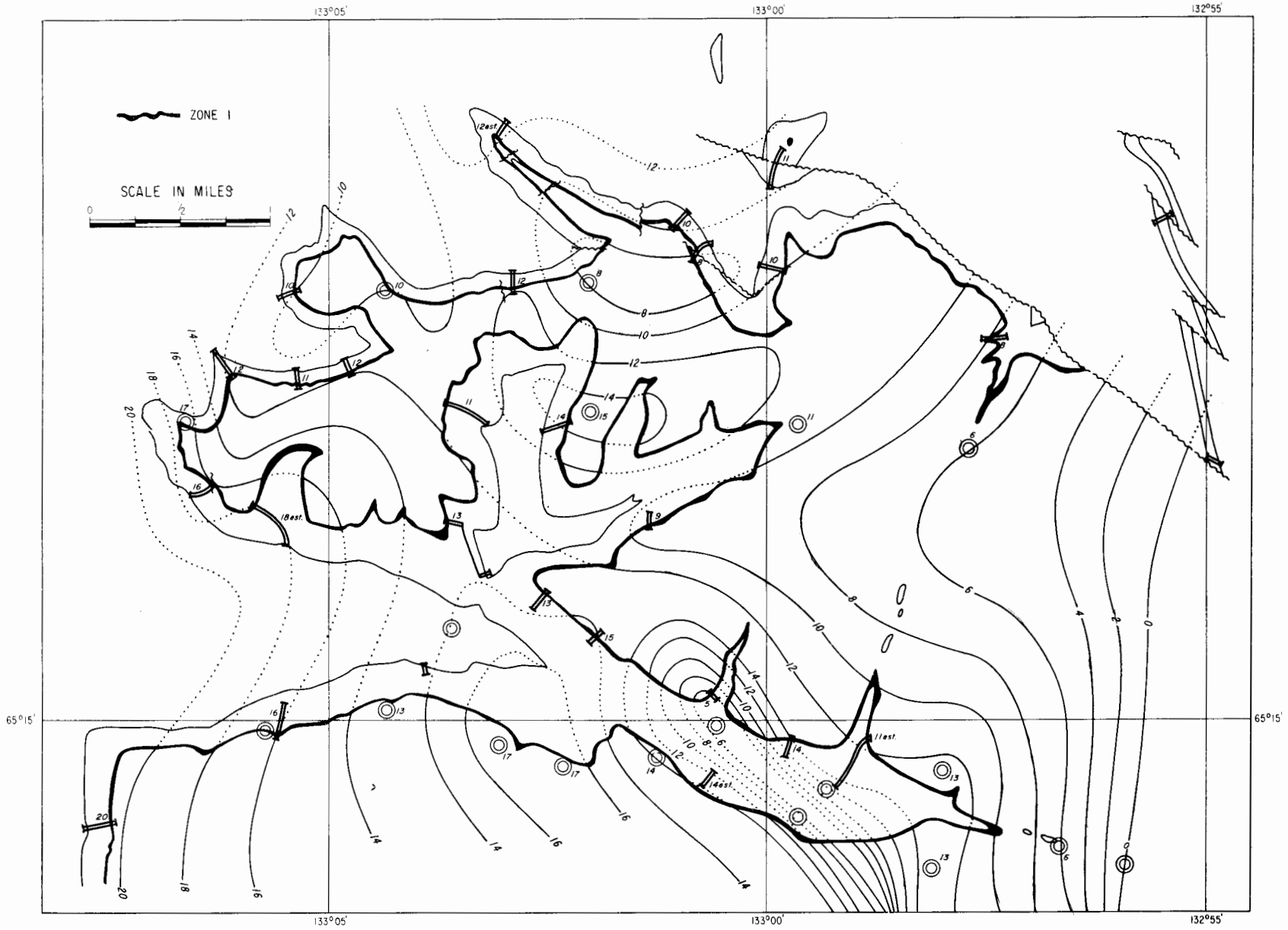
IRON CREEK AREA - ISOPACH OF INTERNAL WASTE, ZONE 5



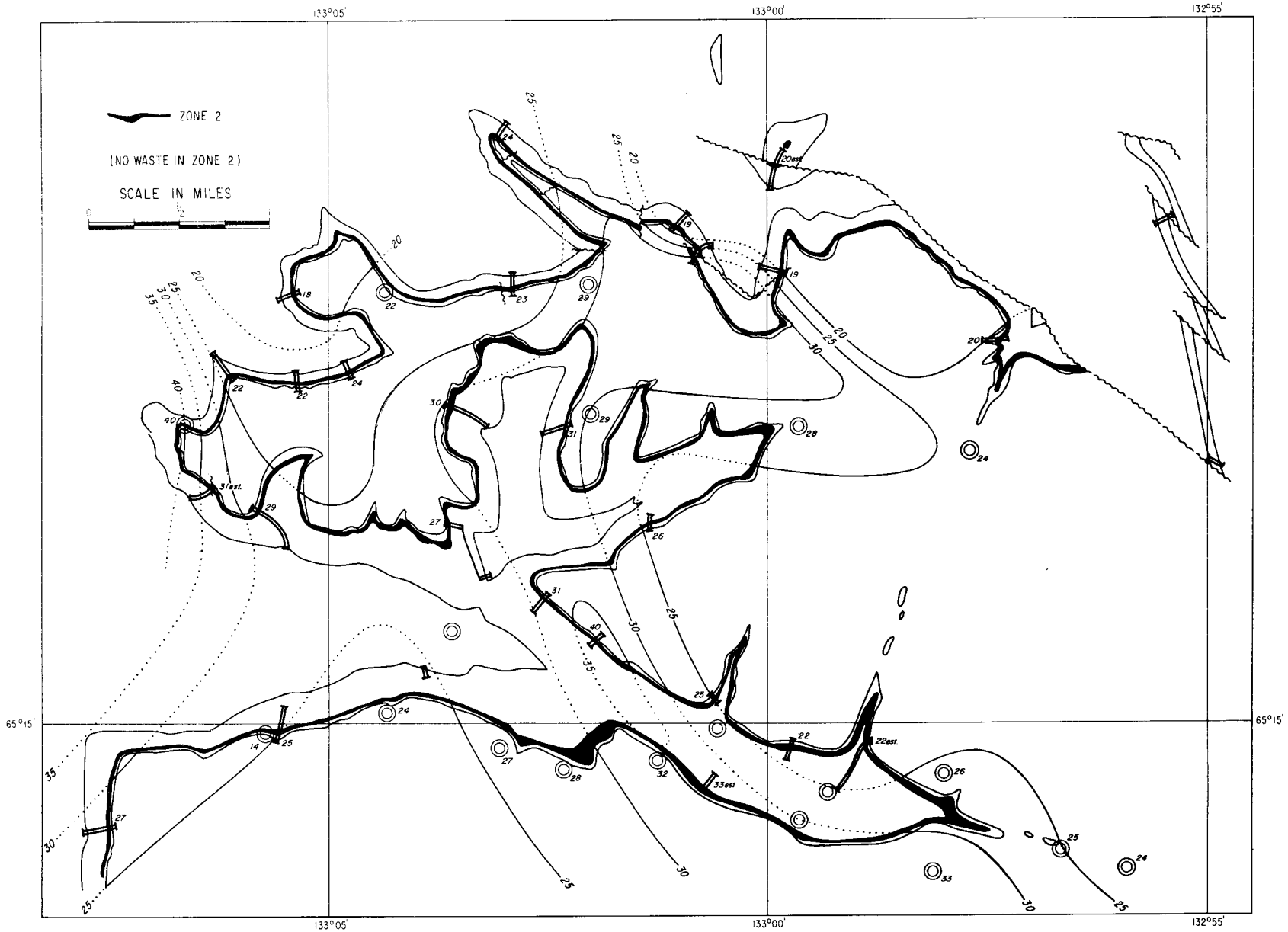
IRON CREEK AREA - ISOPACH, ZONE 6



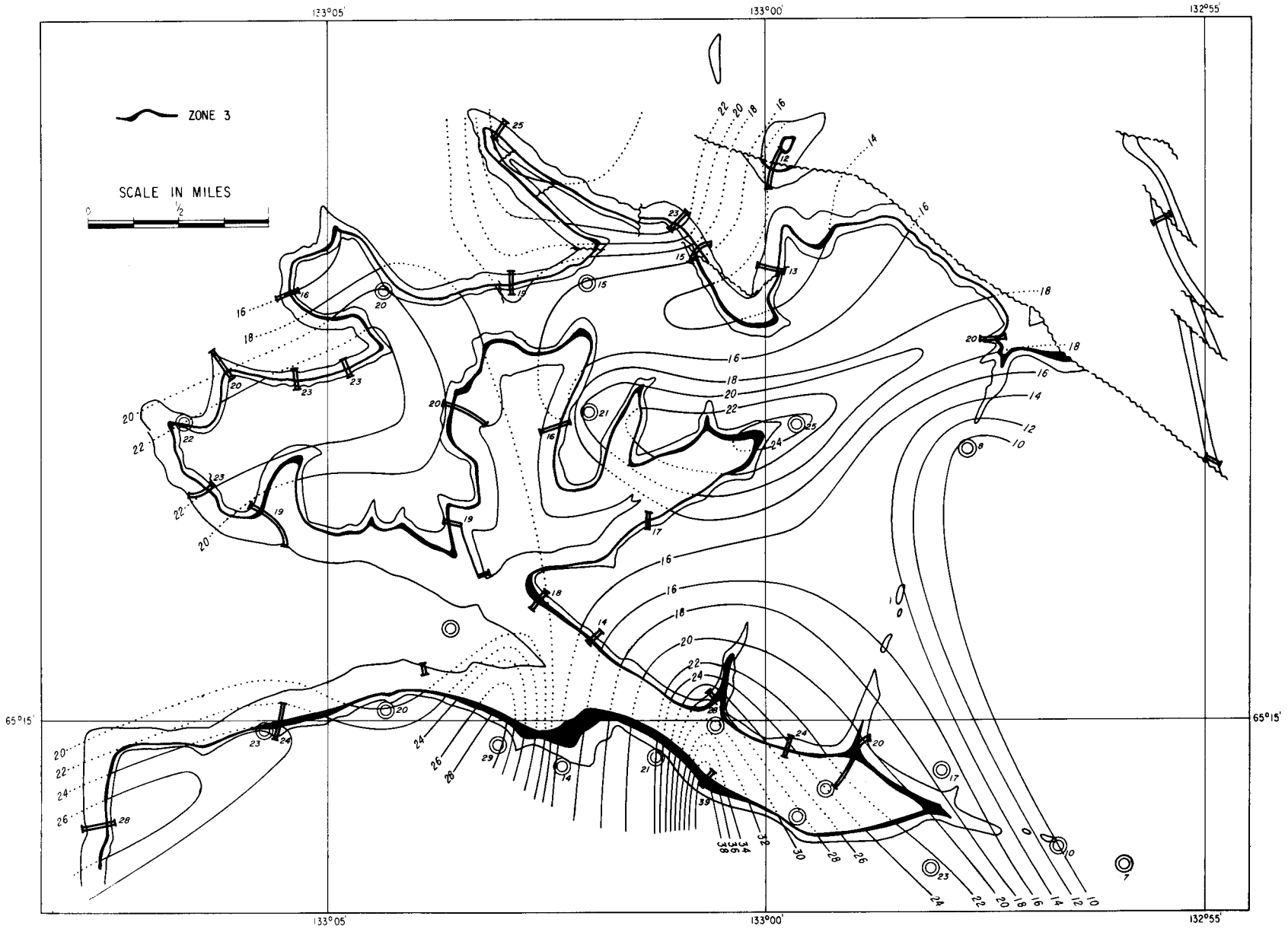
IRON CREEK AREA - ISOPACH OF TOTAL IRON ORE, ZONE I



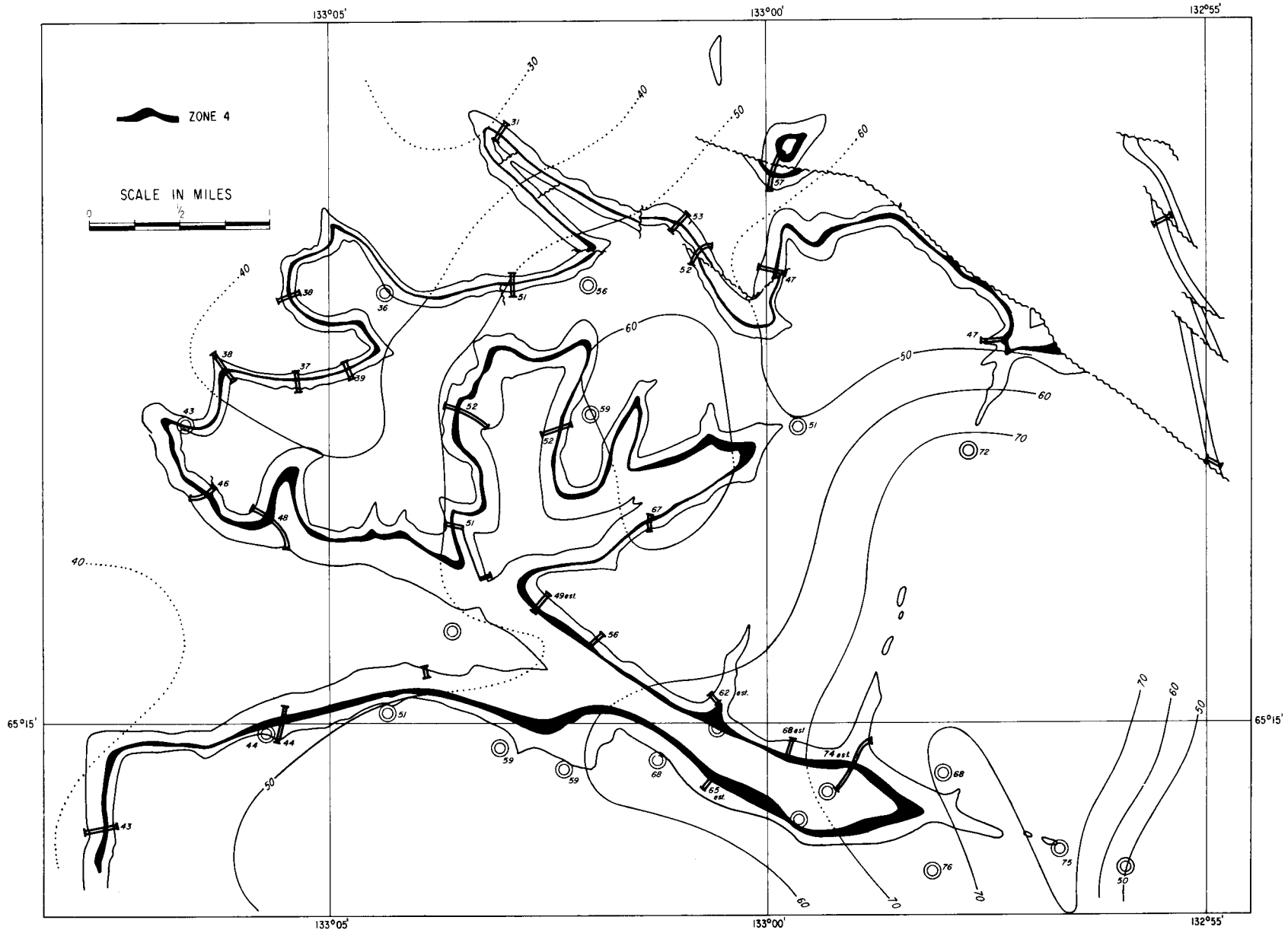
IRON CREEK AREA - TOTAL ISOPACH, ZONE 2



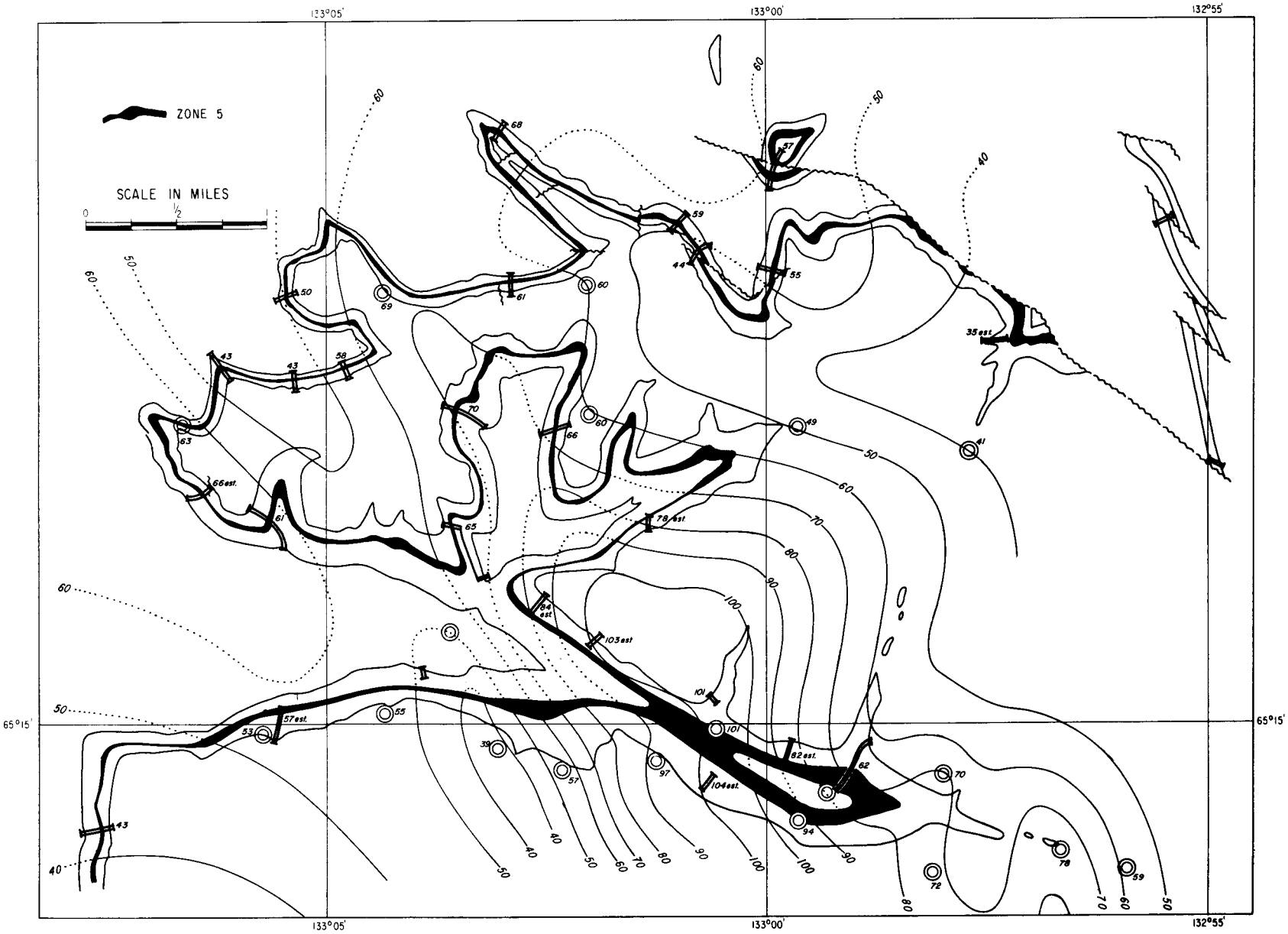
IRON CREEK AREA - ISOPACH OF TOTAL IRON ORE, ZONE 3



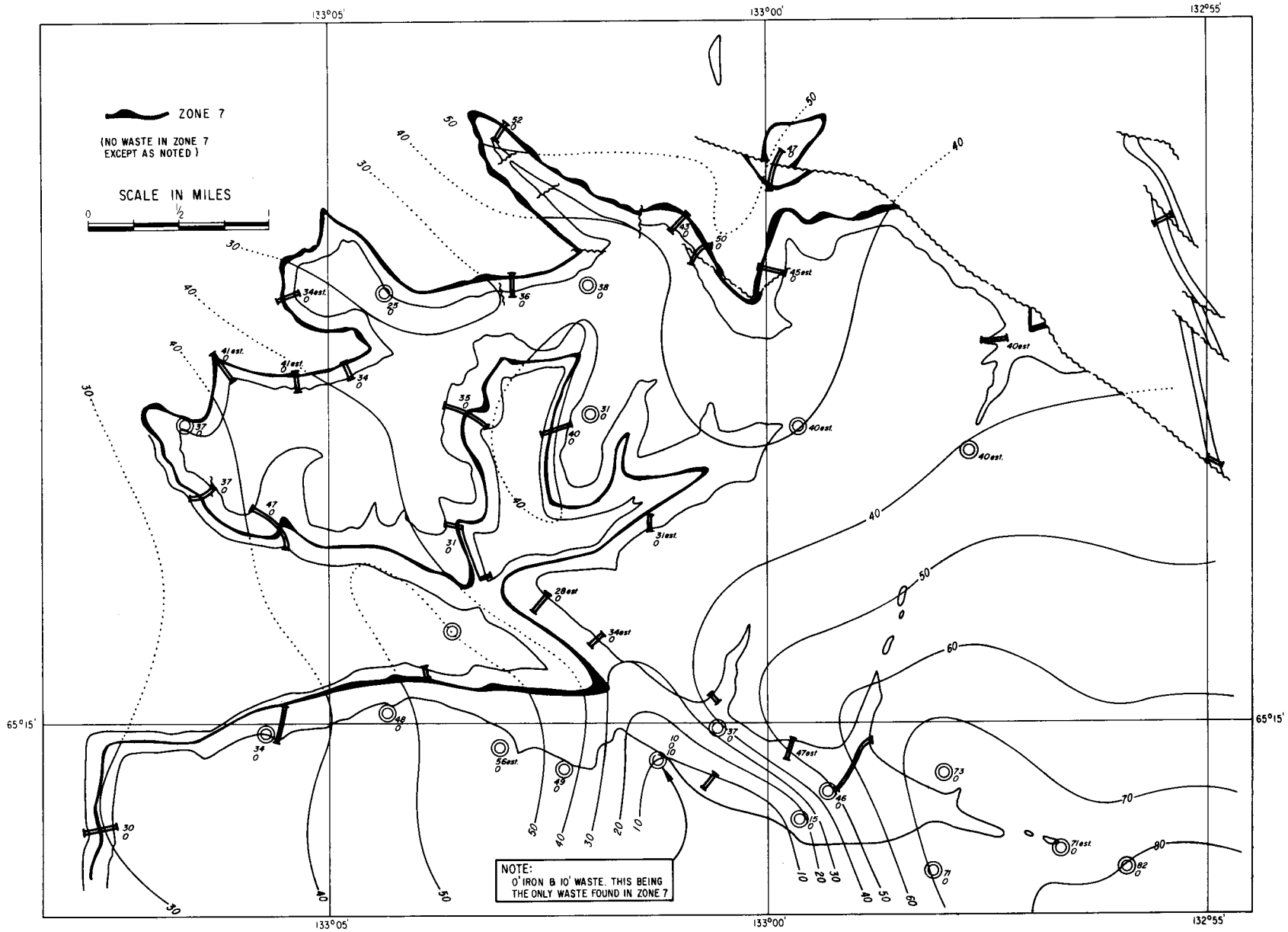
IRON CREEK AREA - ISOPACH OF TOTAL IRON ORE, ZONE 4



IRON CREEK AREA - ISOPACH OF TOTAL IRON ORE, ZONE 5



IRON CREEK AREA - ISOPACH, ZONE 7



Structures Within the Iron Formation

Contact Relations

Clastic members within the iron formation are not usually underlain or overlain directly by the specular hematite varieties of iron formation. The most common types of iron formation at the contacts are thick jasper bands or maroon hematite bands. These lithologic types have clastic affinities since the jasper bands may contain abundant microlenses and grains of jasper aligned parallel to the bedding, and the maroon hematite in places is gradational to mudstone.

The contacts of the clastic members with overlying beds are usually sharp and strictly conformable except where the members are lenticular, in which case overlying beds lap against higher portions of the lenses. The basal contacts of clastic members are conformable or unconformable according to the lithology of the member. Evenly bedded sandstones of the main and upper sandstone markers rest conformably on the underlying bedded rocks without erosional truncation in the examples seen. In one exposure there is a small erosional depression in underlying beds, however, it is filled not with the sandstone, but with brown sandy carbonate. In another exposure the sub-stratum has pulled apart and partly collapsed into the resulting cavity; the remainder of the cavity has been filled with sandstone, by either deposition or inflow.

Basal contacts of conglomerate members and pebbly mudstone partings in the iron formation are usually undulating, owing to the effects of variable compaction and flowage of underlying beds, or from the effects of erosional truncation which is especially common at the base of conglomerate members. Some beds immediately below lenses of clastics or carbonates are folded and truncated in a way that is suggestive of smearing due to drag, either by horizontal flow of the lenses during the process of deposition or by horizontal sliding after deposition.

At one place within the iron formation a hole 10 feet deep and 50 feet wide, probably a channel, is filled with cobble conglomerate composed of carbonate, quartzite, greenstone and jasper. The walls of the hole are steep, irregular and locally overhanging; the conglomerate abuts directly against the walls. The iron formation beneath the conglomerate is down warped, while the iron formation above the conglomerate is gently arched. The 10 feet of conglomerate lies between two stratigraphic horizons which are only 5 feet apart a short distance from the channel location. The difference in interval is compensated by downwarping beneath the conglomerate lends. The downwarping persists at least as far as the next conglomerate zone below, which is 13 feet lower in the section. The great difference in the amount of warping above and below the conglomerate suggests that not all of it is due to compaction, and that part of the warping beneath the conglomerate was present at the time of deposition.

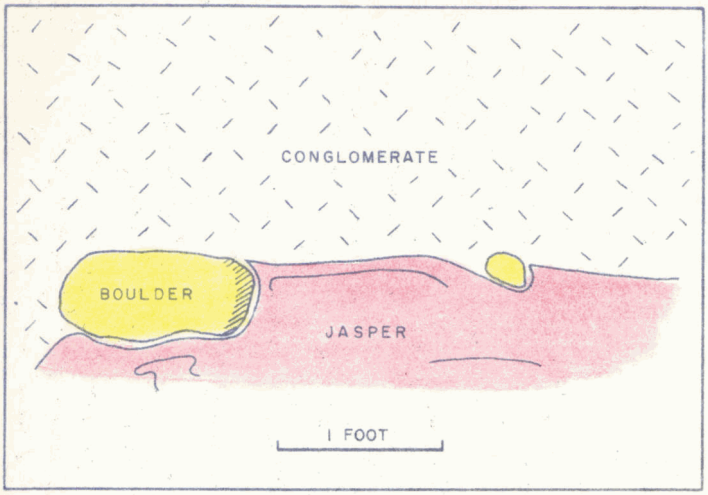


FIG. a
CONTEMPORANEOUS DEFORMATION OF JASPER BY BOULDERS AND COBBLES

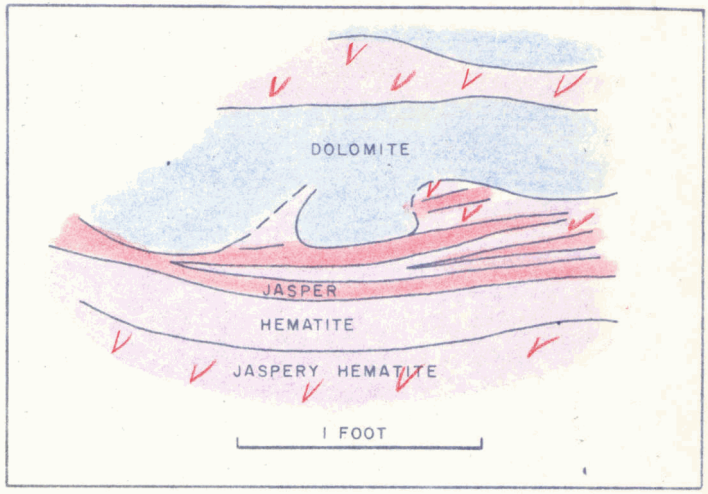


FIG. b
LOAD CASTINGS OF DOLOMITE IN UNDERLYING IRON FORMATION

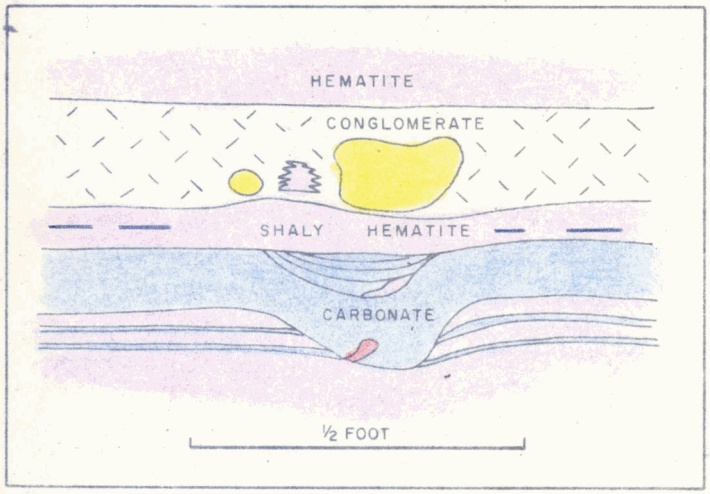


FIG. c
CONTEMPORANEOUS BUCKLING OF CARBONATE BED WITH SEDIMENTARY INFILLING ABOVE & COMPACTION BELOW

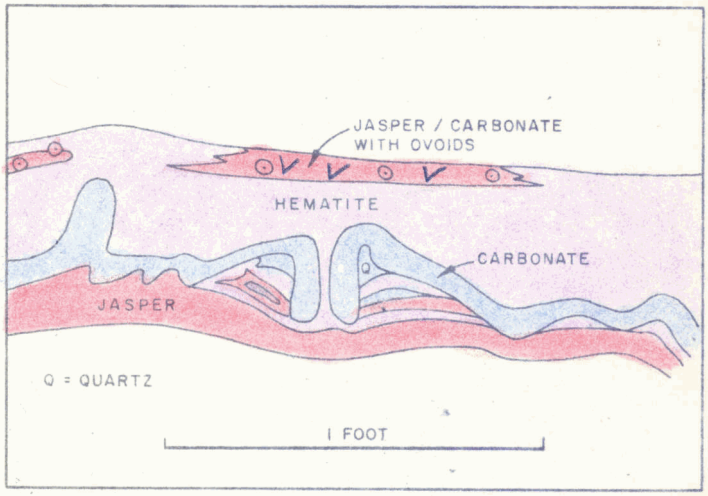


FIG. d
CONTEMPORANEOUS BUCKLING OF CARBONATE BED WITH INTERNAL DEPOSITION IN ANTICLINAL VOIDS

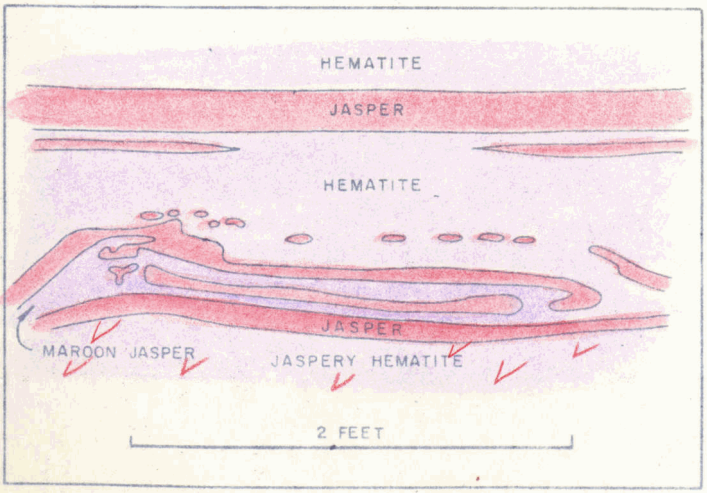


FIG. e
NAPPE-LIKE STRUCTURE IN IRON FORMATION

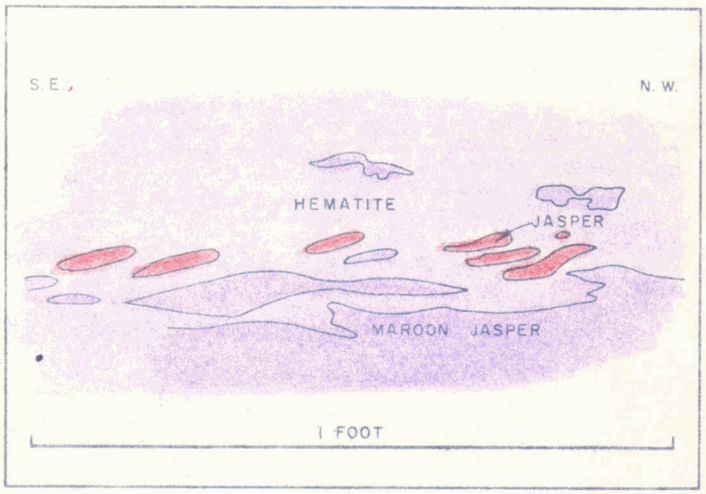


FIG. f
IMBRICATED JASPER LENSES PROBABLY DUE TO FLOWAGE FROM LEFT TO RIGHT

The basal contact of a conglomerate member in the lower-middle iron formation is uneven on account of contemporaneous erosion and plastic flow of the underlying iron formation (jasper). In one place the basal stones of the conglomerate have been partly imbedded in the jasper (Figure A, page 65). The asymmetry of the resulting impressions indicate that the stones were moving in a northwesterly direction immediately prior to deposition.

Structures

The iron formation and associated beds contain sedimentary structures that provide clues to the depositional environment. Structures of this type are bedding, drape structures and contemporaneous flowage and drag folding.

Bedding

Bedding is absent in most conglomeratic, carbonate and mudstone members. The sandstones may be laminated, cross bedded, flat bedded or occasionally swirl-bedded from slumping, but a few are massive. The jasper and hematite layers of the iron formation are occasionally very finely laminated internally but more often are without visible bedding apart from the layering itself.

Sandstones overlying the iron formation contain cross bedding that dips northwest and southwest. Sandstone in a drill core from the same part of the section contains cross beds that are oriented in a spiral sequence; the dip direction of the individual sets changes progressively more than 90° within a stratigraphic interval only 1½ feet thick. The fact that the change is progressive indicates that the sandstone is some kind of depositional unit and is not the result of a succession of unrelated deposits from random directions. In this particular sandstone the wide variation in current direction seems to rule out deposition by turbidity currents, which presumably flow down a regional slope having a fairly permanent direction of inclination. The pattern suggests large scale eddy currents that changed in direction with time, such as are present in delta areas or coastal passages. The sandstone lies a short distance above the jasper-hematite sandstone. It was deposited shortly after the iron formation had emerged and had been partly eroded, so that the water may still have been relatively shallow. The cross bedding of this sandstone contrasts with the flat bedding of sandstones and iron ore within the iron formation.

Marker sandstones within the iron formation are flat bedded, without visible cross bedding. This type of bedding is difficult to interpret in terms of depositional environment, but when considered together with the fact that the sandstones are widespread markers, it seems to indicate a uniform subaqueous environment.

Graded varve-like rhythmic bedding has been seen in weathered rubble and in drill cores of siltstone and shale, but is rare. Of course well bedded clastics are not particularly abundant in the section anyway, so the scarcity of graded bedding is partly accounted for. (Figure 2, page 68) is an example of graded bedding in a drill core. The graded rhythmic bedding is good evidence that the beds involved were deposited by settling of sediment out of suspension.

Ripple marks and mud cracks were not seen anywhere in the iron formation and associated beds, although some time was spent searching for them. The apparent absence of these features suggests that there has been little or no very shallow water deposition.

Pebbly mudstones in the section differ greatly from the sandstone members, since features due to grain by grain deposition are absent. Bedding is massive or absent, sorting is absent, and the long dimensions of pebbles are either randomly oriented or else locally show some preference for vertical, inclined or horizontal orientation. The type of orientation varies in different parts of pebbly mudstone units, giving the impression that coarse swirl patterns may be present. The absence in the pebbly mudstone of features attributable to water action indicates that the sediment very likely was not transported and deposited by currents of water. The pebbly mudstone fabric is illustrated in Figure 1, page 68.

On the basis of limited work, individual pebbly mudstone members are 10-100 feet thick and are separated from each other by members of sandstone or close-packed conglomerate. These members of sorted clastics are probably partly derived by winnowing of the muddy sediment on which they rest, but in some cases the lithologic constituents are not the same and consequently the sorted sediments must have come from an outside source.

Compaction Structures

Compaction structures are seen beneath isolated pebbles and boulders in the iron formation, and beneath some lenses of clastic carbonate rocks. The layers beneath large boulders have been squeezed out laterally into swells which are thicker than the equivalent interval outside the influence of compaction. The swells include a few layers that pinch out both towards and away from the compacting object (Figure 2, page 40). Beds flanking and immediately overlying the object causing the compaction show overlap and compaction where the contact is steeply inclined. Compaction has also taken place beneath clastic and carbonate lenses but the buldging effect has been observed in only one place, in which a layer of carbonate had been buckled, producing cavities under the anticlines that were filled with hematite, carbonate and quartz (Figure D, page 65). These several compaction structures indicate that the hematite and jasper was very soft, plastic and highly compactible when deposited.



Figure 1

Polished section photograph of conglomeratic sandy mudstone in post iron formation interval. Note random orientation and lack of sorting. The jasper fragment was derived from a bed of jasper; it shows faint even laminations. The granular dark greenish pebble in the lower right is a quartzite fragment. Width of field 2 cm.



Figure 2

Polished section photograph of rhythmically bedded and graded fine sediment in post iron formation interval. Dark zones are siltstone, and red-brown zones are mudstone (shale). Length of field 2.35 cm.

Slump and Flow Structures

Structures due to slumping and flowage are fairly common in the nodular banded type of iron formation. They consist of dislocated jasper fragments that were originally jasper layers, and also of upended jasper nodules that presumably developed their oval outlines while in a horizontal position (Figure 1, page 70). Carbonate bands in the iron formation have been deformed into small folds or have been broken and telescoped (Figure 2, page 70, Figures D, E, F, page 65).

The structures can be classified into extension and compression types. In extension structures the fragments are separated by gaps, whereas in compression structures the fragments are telescoped or imbricated, and layers are folded in places. Where movement has been extensive the structure becomes chaotic and flow-like, and cannot be readily classified. This last type of structure is found in nodular iron formation and probably also in the pebbly mudstones.

Both the extension and compression structures are to be expected if unconsolidated beds moved down a depositional slope, the extension structures occurring where the movement began, and compression structures where it ended. The direction in which the movement took place is indicated by imbrication of jasper fragments and by asymmetry of the folds. On the basis of these criteria the direction of movement (and the depositional slope) was northwestward (Figure F, page 65).

Petrology of the Iron Formation

Petrology of the Clastics

The Snake River iron formation is located within a thick sequence of conglomeratic mudstones. Several members of this sequence consisting of sandstone, conglomerate and conglomeratic siltstone, having thicknesses in the 5 to 50 foot range, occur within the iron formation along with the occasional bed, ranging in thickness from 1 to 2 feet, of brown dolomite, red shale and volcanic tuff. Of the several clastic horizons found within the iron formation, the upper sandstone bed, the lower sandstone bed and the lower conglomeratic mudstone member (Zone 6) have proven to be most useful markers for structural control due to their continuity.

Well sorted, fine clastic sediments make up only a small part of the sedimentary sequence. Most of the silt and clay is found in the matrix of the unsorted conglomeratic mudstones. However, there are a few thin shale members which rarely exhibit graded bedding and rhythmic varve-like laminations. Within the iron formation some of the well bedded ores include paper-thin shale partings between the individual beds.

Conglomeratic Mudstone

The pre-iron formation conglomeratic mudstone has been examined only on a macroscopic scale. It is similar to the conglomeratic



Figure 1

Polished section photograph of disturbed iron formation, showing steeply inclined elongate jasper masses in hematite. Scale about twice natural size. Bedding direction horizontal.



Figure 2

Polished section photomicrograph of diagenetically crumbled primary dolomite laminae in hematite matrix. Width of field 11 mm.

mudstone found elsewhere in the section apart from some differences in pebble lithology. For example, pebbles of quartzite and finely crystalline carbonate are more common than greenstone, whereas in the post iron formation conglomeratic mudstones, greenstone pebbles are more common.

Conglomeratic mudstone of the post iron formation interval is illustrated in Figures 1-2, page 72. It contains jasper fragments that have been derived by erosion of a zone lithologically similar to the iron formation. However, the fragments may not have originated in the iron formation itself, since conglomeratic mudstone beds both above and below the iron formation also contain red jasper. Other constituents of the conglomeratic mudstone illustrated in Figures 1-2, page 72, are quartzite and carbonate pebbles, quartz grains and grains of red argillite and greenstone. The matrix is composed of red ferruginous mudstone. The random orientation and lack of sorting are characteristic of mass transportation without benefit of aqueous sorting.

Pebbles and grains of finely crystalline carbonate in the conglomeratic mudstones, as well as fragments of volcanic glass and lava and lenses of fine tuff, have been partly to completely altered to chlorite by post depositional processes. The conglomeratic mudstone member (Zone 6) is an unsorted and unoriented mixture of subangular sand grains and occasional pebbles in a dark red-brown mudstone matrix comprising perhaps 75% of the rock. The grains consist chiefly of quartz, plagioclase and orthoclase. Many of the fledspar grains have been altered to carbonate. Minor constituents include chert, finely crystalline carbonate and lava fragments. The member is texturally similar to mudstones overlying the iron formation and very likely has a similar origin.

Sandy mudstone within the iron formation is illustrated in Figure 1, page 74 . The grains are composed chiefly of quartz in a matrix of opaque ferruginous mudstone. The light coloured sandy lenses in the figure are sericitic. The opaque mudstone matrix includes faint coarse lenses of slightly different coloured mudstone which are probably unconsolidated fragments from the source area. Perhaps the wispy sericitic patches have a similar origin, but if so, their indefinite, irregular outlines would preclude much transportation. The lenses and patches are distincly oriented parallel to the bedding direction, but the quartz grains show no tendency to be concentrated in stringers or laminae; they are scattered at random through the matrix. The conflicting implications of aligned lenses of sediment and of the random fabric in sandy parts of the rock can be resolved if the randomness is considered to be primary while the alignments are secondary and originated through compaction of the sediment. A rock of this type may be formed by deposition within a highly fluid mud flow.



Figure 1

Polished section photograph; conglomeratic mudstone. Note buff carbonate fragment in lower right surrounded by rim of replacing chlorite. Greenstone lower left; argillite right centre; quartzite left centre. Width of field about 2 cm.

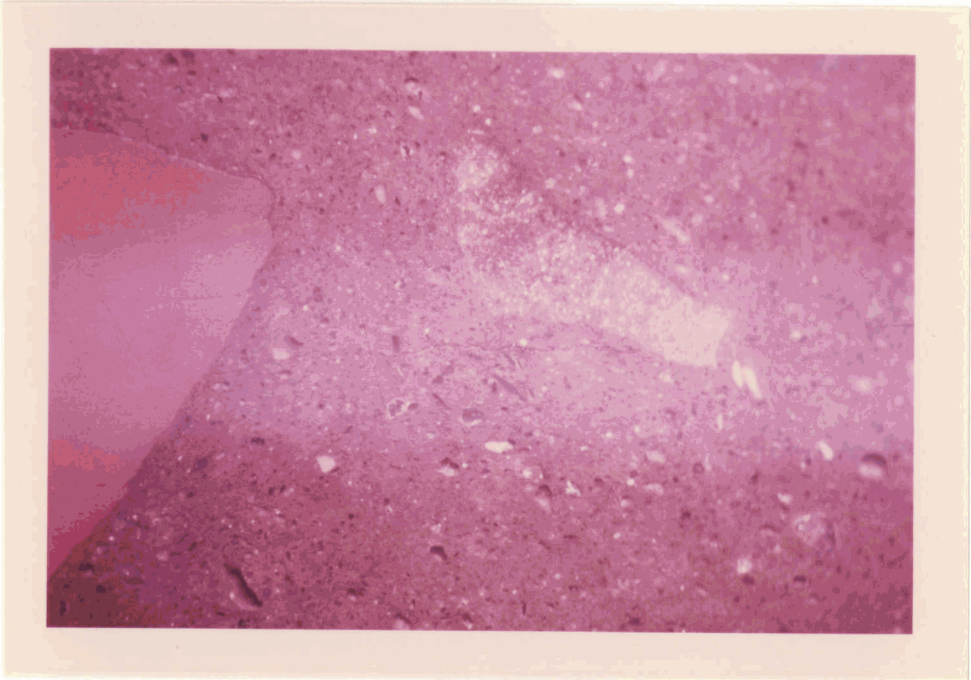


Figure 2

Polished section photomicrograph, showing detail of sandy mudstone matrix, vicinity of jasper fragment appearing Figure 1, page 68. Width of field 9.4 mm.

Sandstone

The upper sandstone marker is a dark reddish grey, fine to medium grained clastic having faint, slabby, even bedding. The matrix which consists chiefly of chlorite and minor amounts of ferruginous mudstone, makes up about one-quarter of the rock. A point count determination of the sample illustrated in Figure 2, page 74, shows that it is composed of 23% matrix, 25% quartz grains, 15% phyllite or sericitic siltstone grains, 13% argillaceous earthy hematite grains, and 8% each of grains composed of sparry carbonate, microcrystalline carbonate and chlorite. Grains of leucoxene are fairly common, along with traces of plagioclase, perthite, chert and metamorphic quartzite.

Quartz grains have been coated with layers of earthy hematite while some chlorite, phyllite, carbonate and lava fragments show pervasive alteration to earthy hematite. Part of the sandstone matrix is ferruginous. The sandstone shows little variation in composition, although the matrix may comprise a larger proportion of the rock, and the relative abundances of the chloritic and ferruginous components may be reversed. The lower sandstone marker is lithologically similar to the upper sandstone in most respects, including many details of texture and composition. However, the main sandstone differs in containing common green chlorite shards, some of which are partly replaced by calcite.

Tuff

The iron formation a few feet beneath the upper sandstone member contains a thin marker bed that is remarkable since it is composed chiefly of dark green chloritic volcanic shards and oval volcanic mudballs (Figure 1, page 42). Scattered rounded quartz grains in the rock show that it is probably of subaqueous origin rather than of subaerial, purely volcanic derivation.

Petrology of the Ore

Ore Components

The bulk of the ore consists of microcrystalline hematite and chalcedonic quartz in several varieties of aggregation. Calcite, dolomite, apatite, goethite and finely crystalline quartz are minor constituents that are locally abundant. Trace components include chlorite, ferroan dolomite, siderite, collophane or koninckite, wavellite, barite, muscovite, pyrite and chalcopyrite. The ore also contains scattered grains and occasional lenses of clastic material which consists of quartz, finely crystalline carbonate and altered volcanic rocks.

The hematite is most commonly in the form of irregularly bounded, interlocking crystals ranging in size from 5 microns to 200 microns and averaging 30 microns. (Figures 1, 2, page 75).

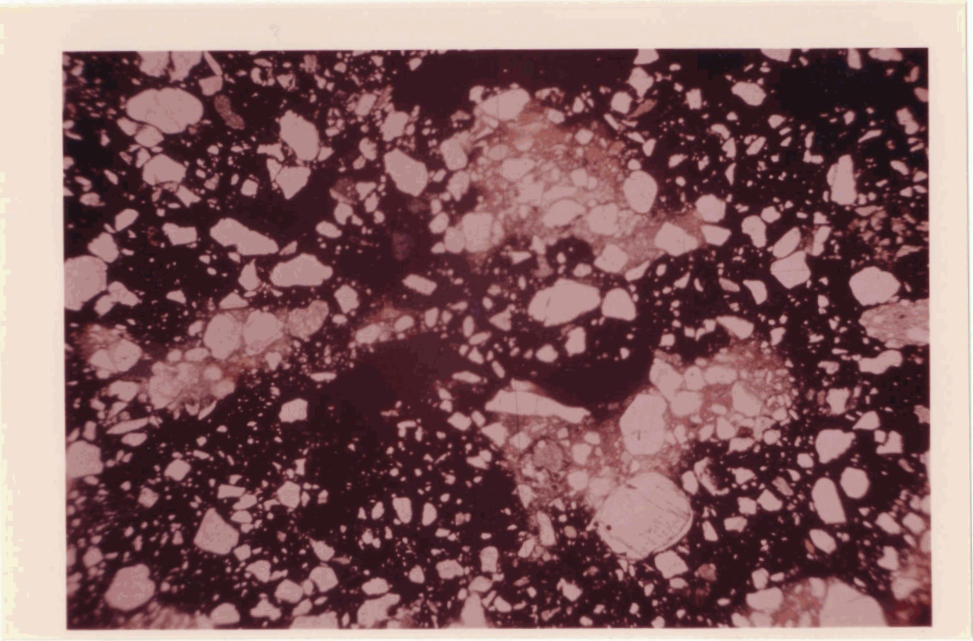


Figure 1

Thin section photomicrograph, X20: Muddy sandstone containing intraformational lumps of argillaceous sand. Plane light.

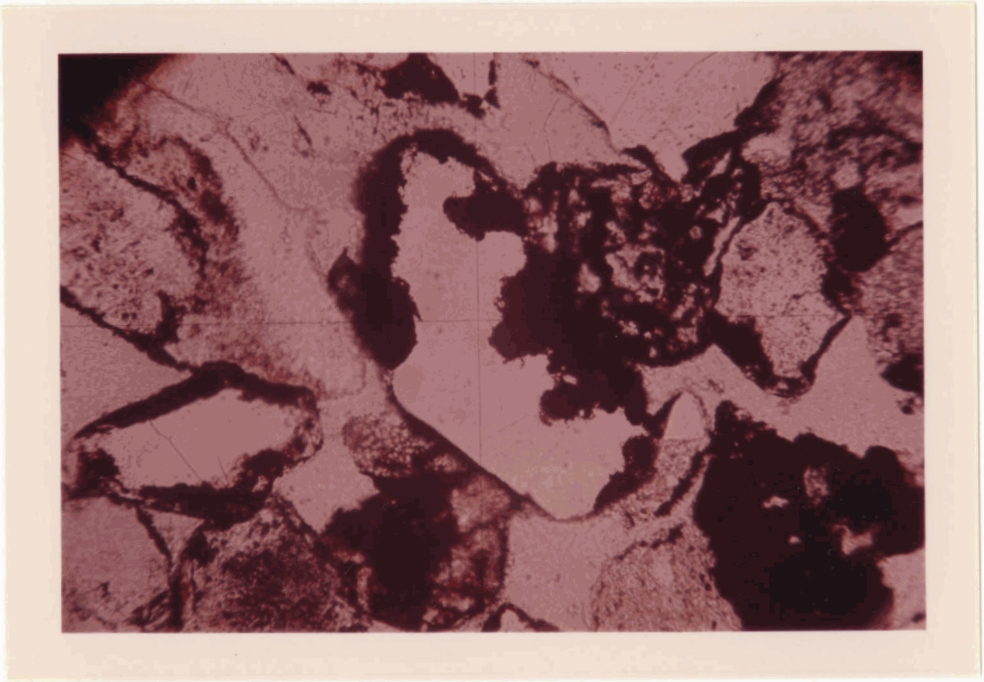


Figure 2

Thin section photomicrograph, X235: Corroded and coated quartz grains in sandstone. The coating is reddish brown cryptocrystalline earthy hematite. Plane light.

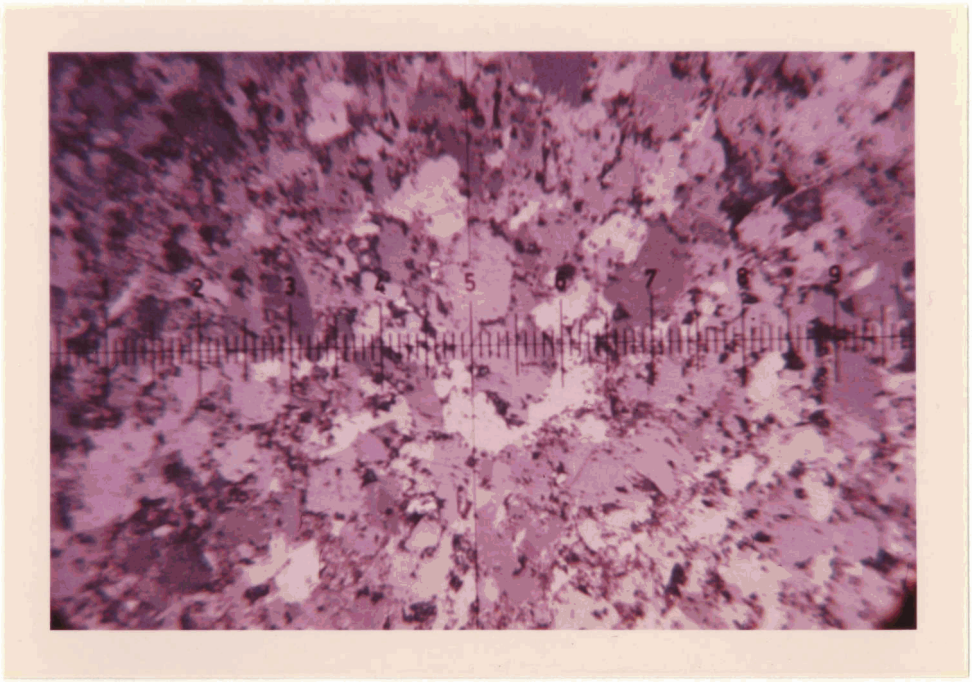


Figure 1

Polished section photomicrograph, X200: Crystalline hematite; gangue mainly interstitial (dark). Crossed nicols.

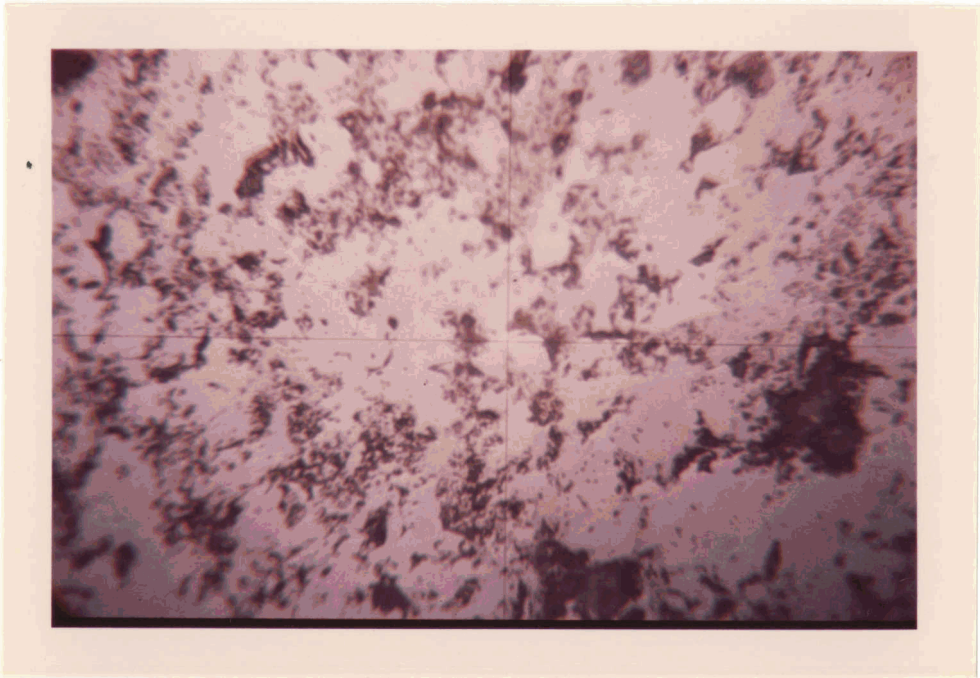


Figure 2

Polished section photomicrograph, X400: Crystalline hematite (light) with gangue (dark). Plane light.

In some laminated types of ore the hematite is in well formed, relatively coarse crystals that show polysynthetic twin laminae. In another ore type there are patches of bladed hematite that are evidently replacements of gangue minerals. These two latter types comprise a minor part of the ore.

Hematite also occurs in the jasper gangue in the form of tabular crystals from less than 1 micron to 25 microns in diameter. The crystals occur singly and in clot-like aggregates. In some parts of the gangue the hematite crystals are relatively coarse, and are arranged in oblique lattice-like patterns and rosettes. In the maroon jasper the hematite is abundant and occurs as distinct microcrystals and aggregates (Figure 1, page 77). However, in the red jasper the hematite occurs as very fine dusty clouds of crystals 1 micron or less in size (Figure 2, page 77). Some crystals show a yellowish colour and prismatic habit which suggest that goethite may be present.

Chalcedonic quartz, which comprises most of the gangue, is colourless where the hematite is absent. Under low magnification in thin sections the gangue appears to be composed of very fine grains of quartz. However, under high magnification these grains are intricately interlocking masses which probably have a radially fibrous texture on a submicroscopic scale since they show wavy, migratory extinction lines. The aggregate boundaries, which probably are composed of interlacing fibers from adjoining areas, are not well defined and tend to migrate and change shape during rotation of the microscope stage. The textures resemble those of chalcedony but the material is clearly quartz. For this reason it has been called chalcedonic quartz. Occasionally it is distincly granular and extinguishes uniformly grain by grain. Such areas are likely the result of local recrystallization. Chalcedonic quartz is illustrated in Figure 1, page 77.

Calcite and dolomite are common primary and secondary constituents in the ore. The primary varieties are sedimentary or early diagenetic, and were deposited while the ore was being laid down or soon afterward. Rarely the hematite contains small oval concretionary nodules of light yellowish gray fine grained dolomite which are probably of primary or early diagenetic origin (Figures 1, 2, page 78). Also primary are the laminae or lenses of fine grained dolomite (Figure 1, page 79) and the clastic grains of crystalline limestone and dolomite (Figure 2, page 79). Some carbonate spherulites and the few oolites that were observed are also primary or early diagenetic.

Relatively coarse crystalline patches and isolated crystals of calcite and dolomite (?) in the siliceous gangue areas are secondary. The patches and crystals are evidently metacrysts that have replaced siliceous gangue, as they are bounded by crystal faces and contain scattered inclusions like those in the surrounding gangue.

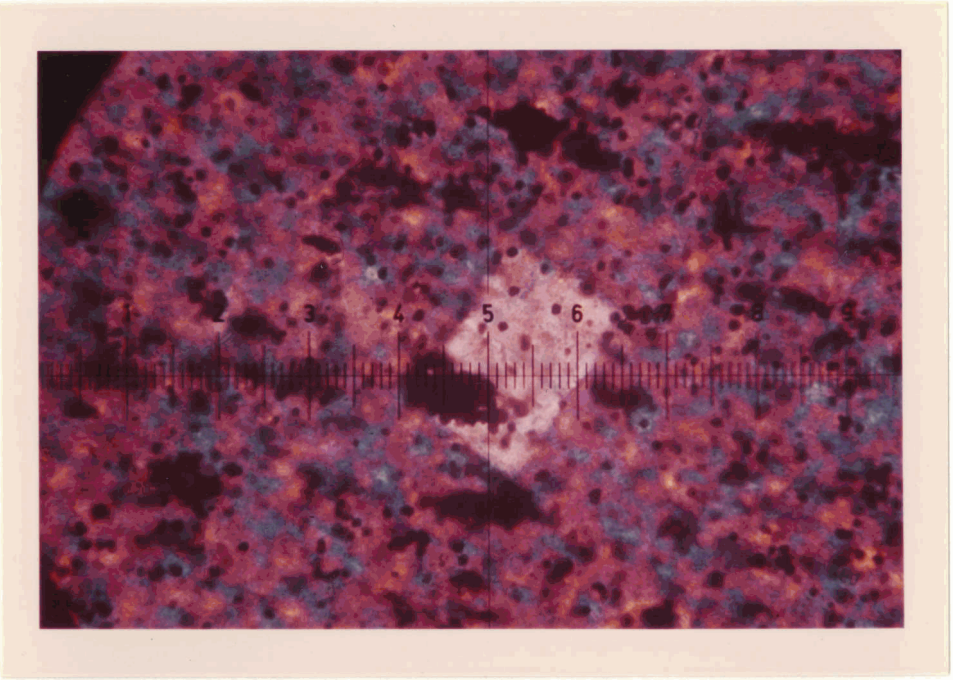


Figure 1

Thin section photomicrograph, X550: Chalcedonic quartz (blue and yellow) containing scattered grains and clots of hematite (dark), and rhomb of replacement calcite in centre. Crossed nicols, gypsum plate.

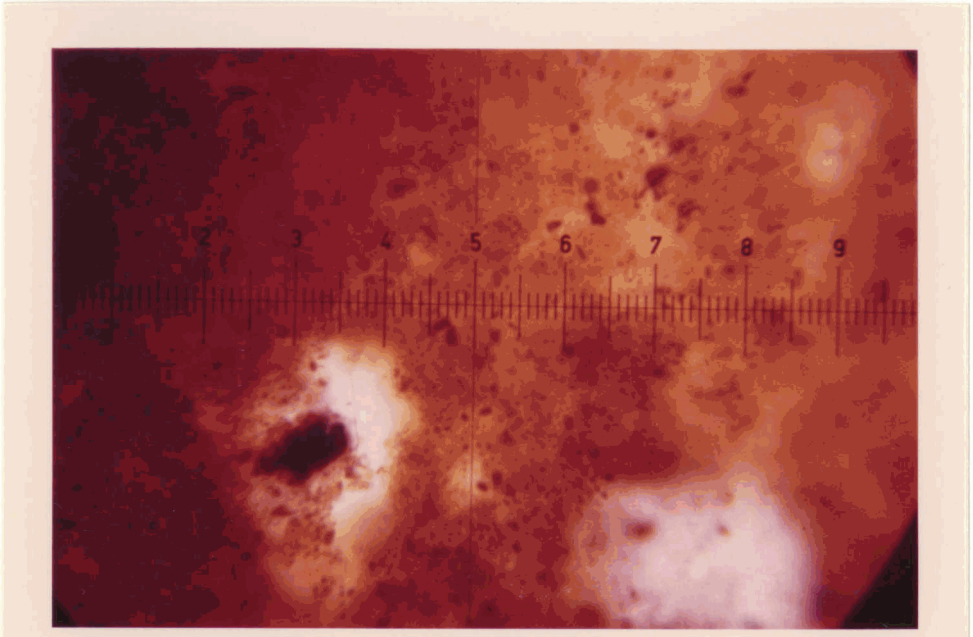


Figure 2

Thin section photomicrograph, X1100: Partly clarified red jasper showing tiny scattered crystals of hematite and goethite. Unclarified phase on left. Plane light.

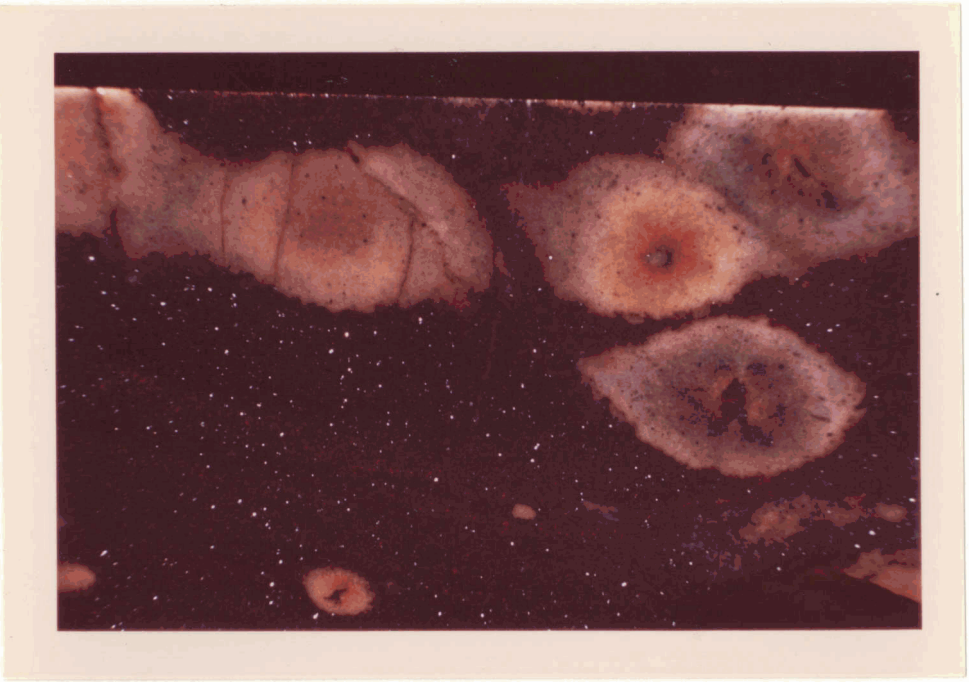


Figure 1

Polished section photograph, X6: Nodules of fine grained dolomite in hematite, vertical section. Oblique illumination.

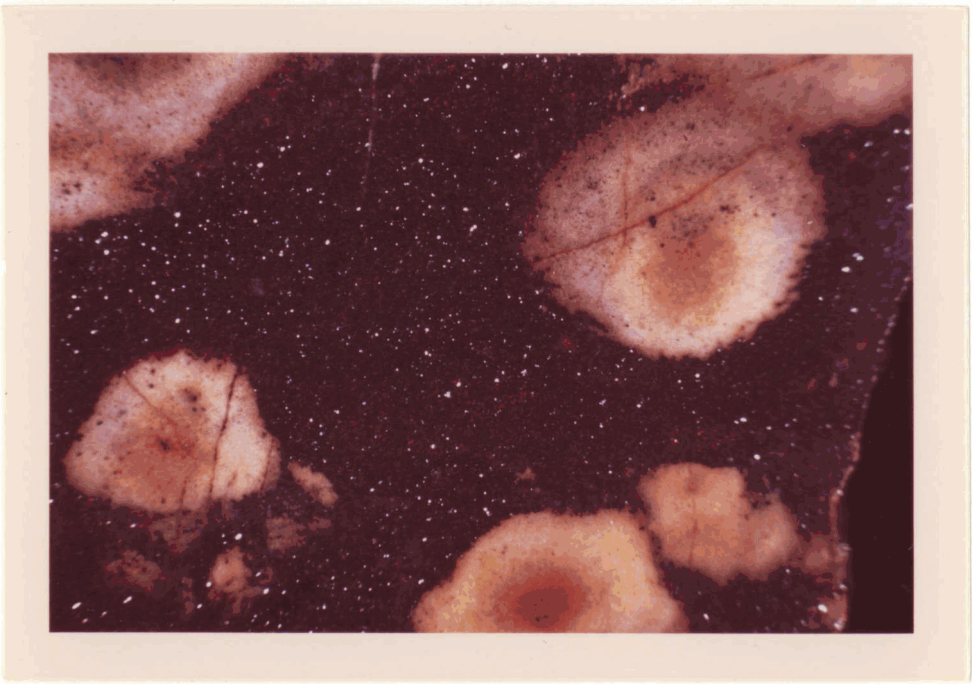


Figure 2

Same as above figure, but bedding plane section, X6. Oblique illumination.

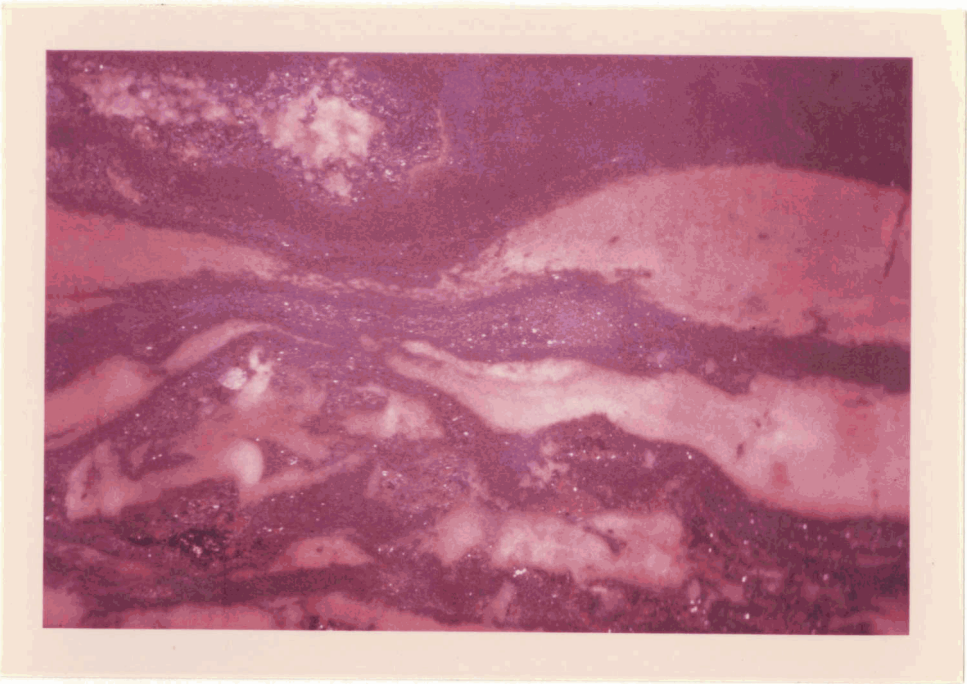


Figure 1

Polished section photomicrograph, X10: Primary dolomite beds and lenses in hematite showing stretching due to compaction, and knotting from drag due to lateral sliding. Oblique illumination.

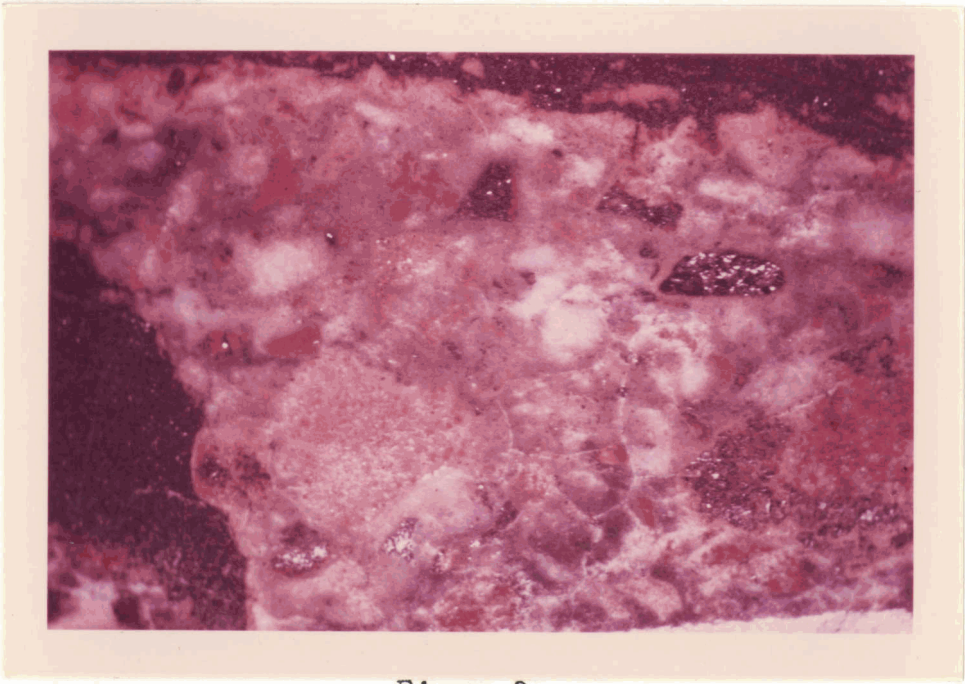


Figure 2

Polished section photomicrograph, X10: Clastic carbonate in hematite. The fragments are fine grained dolomite partly altered to red jasper and specular hematite in matrix of sparry dolomite. Oblique illumination.

Very small patches and lenses of crystalline calcite which are commonly bordered by inward projecting hematite crystals are contained in the dense hematite phase of the ore. The carbonate lenses are probably secondary but it is not clear whether they are cavity fillings, recrystallized primary lenses, or secondary segregations.

Apatite, which is abundant in the chalcedonic quartz (Figure 1, page 81), and is also present in the carbonates, is an important minor component of the ore. The bulk of the apatite is in the form of scattered stubby hexagonal prisms ranging in length from 2 to 35 microns and averaging 10 microns. The prisms are light yellow, light yellowish green or colourless and many include a small mass of crystalline hematite which acted as a centre of growth. Other crystals are zoned, with yellow cores and colourless borders. The apatite also occurs as relatively pure granular laminae (Figure 2, page 81 and Figure 1, page 82) or as small patches of mutually intergranular apatite and hematite.

Due to illumination limitations, very little apatite can be detected in thin sections of dense hematite and opaque gangue. However, chemical analyses show that the opaque areas are phosphatic and consequently must contain some phosphate minerals.

The abundance of apatite varies according to the ore type, and it is often possible to correlate the amount of visible apatite with the type of gangue and, through this, with the mode of deposition. Gangue in the form of spherulites and oval nodules, both of which are growth structures, seems never to contain much visible apatite, whereas gangue containing sedimentation structures (grains, laminations) contains abundant apatite in some of the layers. Also, secondary nodules showing relict sedimentation structures may carry abundant apatite.

Chlorite, in the form of optically negative penninite, is the most common of the trace minerals. It usually occurs in veinlets with carbonate and as a replacement of carbonate rhombs and finely crystalline carbonate granules. Some chlorite patches have angular, clastic outlines and are probably replacements of carbonate grains or volcanic rock fragments. Chlorite grains and chloritic matrix make up an important part of the clastic members, although the original nature of most of the chlorite of the matrix is believed to be altered fine volcanic ash.

Ferroan dolomite is occasionally encountered in the form of small, sharp cornered, zoned rhombs that have replaced chalcedonic quartz gangue. The crystals are rimmed and mottled with dark reddish brown iron oxide that presumably formed by partial oxidation of the carbonate.

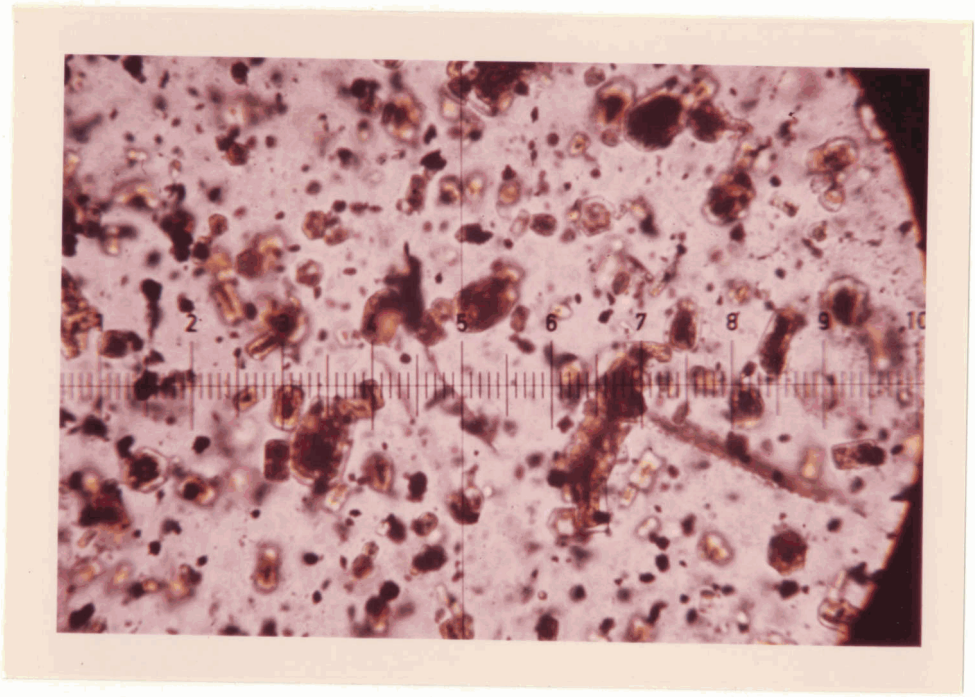


Figure 1

Thin section photomicrograph, X440: Scattered resinous brown apatite crystals in light crystalline chalcedonic quartz. Dark grains are hematite. Plane light.

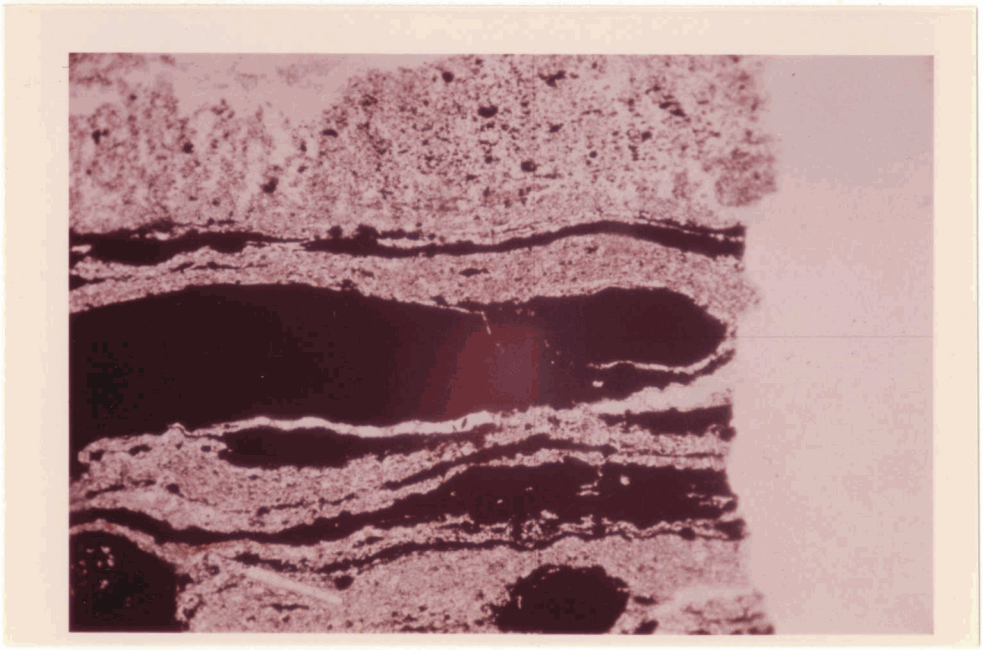


Figure 2

Thin section photomicrograph, X93: Interlaminated hematite (dark), silica, and microgranular apatite (indicated by arrows). Plane light.

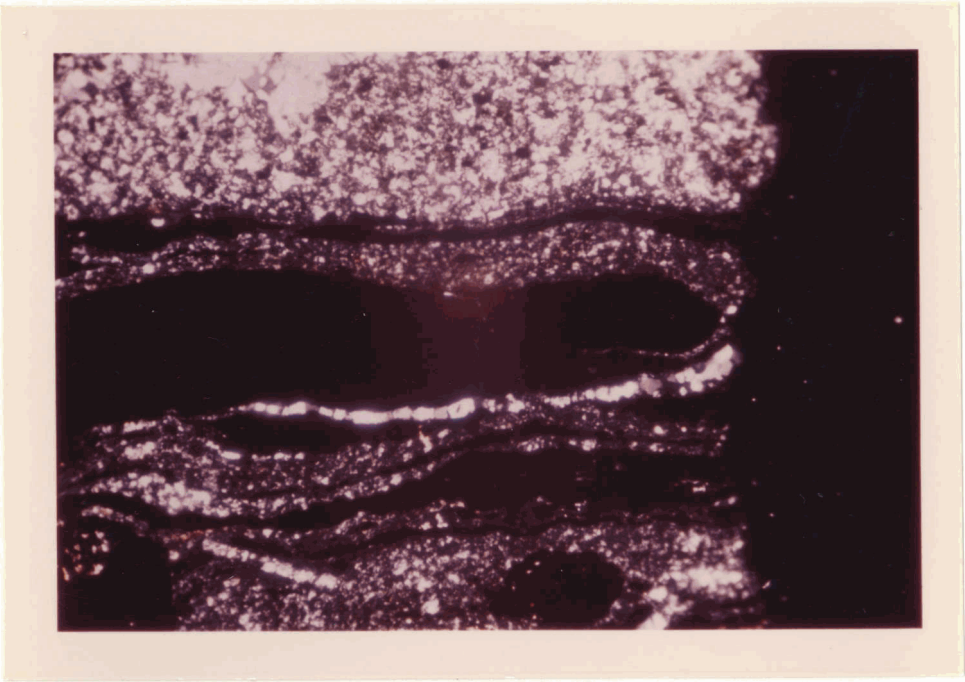


Figure 1

Same as Figure 2, page 81, but crossed nicols.



Figure 2

Thin section photomicrograph, X225: Spheres of yellow collophane or koninckite in siliceous interior of nodule. Plane light.

Wavellite and koninckite (hydrous iron phosphate) or collophane, have been identified in the ore, but are very uncommon. Wavellite occurs as a vein filling; koninckite or collophane are present as minute yellow spheres in a gangue nodule (Figure 2, page 82). Crystalline barite patches associated with granular hematite were observed in a few samples. The barite has apparently replaced some other types of gangue without affecting the associated hematite.

The ore contains occasional crystalline grains of chalcopyrite and pyrite. The sulphides are usually located in siliceous gangue rather than in the hematite but they have also been observed in the clastic members, where some quartzite fragments have been preferentially replaced.

Ore Types

The ore can be classified into three types:

(a) Banded ore,
(b) Nodular ore, and
(c) Complex ore.

These in turn can be broken down further according to the type of nodules or bands. The hematite component of the ore is banded or massive, permitting a further subdivision that is significant in nodular ore types.

A. Banded Ore:

The commonest type of banded ore consists of even beds, one quarter to one-half inch thick, or red or maroon jasper and hematite in about equal amounts. In a few parts of the iron formation the jasper beds are up to six inches thick, and the hematite is in thin partings, while in other parts the relative thicknesses are the reverse. Occasionally, the ore is very finely and evenly laminated, as illustrated in Figure 1, page 84. The laminae appear to be primary deposits of sediment, as they contain abundant fine grains that are distributed and aligned parallel to the bedding.

The banded ores contain scattered grains and small lenses of terrigenous clastics more often than other ore types, and they tend to precede or follow an interval of clastic deposition. This association with clastics and the presence of well defined bedding are indications that the banded ores formed by sedimentation of free particles rather than by growth due to accretion.

Present textures of the hematite of the banded ores are obviously not original. The hematite occurs as an interlocking mosaic of crystals in which microscopic gangue patches occupy positions that are largely intercrystalline (Figures 1, 2, page 75). The hematite crystals are up



Figure 1

Polished section photomicrograph, X10: Interlaminated primary granular red jasper and jasper streaked hematite. Oblique illumination.



Figure 2

Polished section photomicrograph, X10: Fractured red jasper with infill by sparry dolomite and plastic intrusion of hematite, probably before consolidation. Oblique illumination.

to 0.2 mm. across and occasionally show twinning lamellae in the coarsest varieties. However, the average crystal size is much smaller than 0.2 mm. The mosaic texture, the local coarseness of the crystals and the twinning lamellae are all indications that crystal growth has taken place after deposition.

Crumpled vertical quartz veinlets and draped hematite laminae around nodules and clastic grains (Figure 2, page 84, Figures 1, 2, page 86) indicate the degree of compaction which the original hematite bands have undergone. A measurement of the restored length of one crumpled veinlet indicated that the hematite has been compacted to less than half of its original thickness since formation of the veinlet.

The jasper beds or laminae vary in texture according to whether the jasper is of the red or maroon type. Red jasper in thin sections is subtranslucent and cloudy due to the presence of numerous minute crystals of hematite. In reflected light it frequently has a granular texture which is accentuated in places by partial replacement of the granules of hematite (Figure 1, page 87). Red jasper also occurs in two less common varieties, microspherulitic (Figure 2, page 87) and microbotryoidal (Figure 1, page 92). The main constituent of the red jasper is microcrystalline chalcedonic quartz. Maroon jasper is fairly transparent in thin section, due to its well developed microcrystalline texture and is composed of chalcedonic quartz, with varying amounts of microcrystalline hematite in grains and grain aggregates. Other constituents are secondary carbonate metacrysts and apatite.

A third type of siliceous band, resembling maroon jasper, consists of lenticular siliceous nodules containing small amounts of hematite, in a matrix of maroon jasper.

B. Nodular Ore:

Iron formation consisting of massive hematite with little evidence of bedding and containing one-quarter to one-half inch oval or lenticular concretions of gangue is classified as nodular ore. Nodules of red jasper are the most common, followed in abundance by paler red spherulitic nodules of silica and calcite (Figures 1, 2, page 86). Nodules of light brown, finely crystalline dolomite are occasionally present (Figures 1, 2, page 78).

The hematite component of nodular ore is fine grained and averages 15 microns in size. The hematite is usually massive without visible bedding lineation. However, some of it carries wispy gangue laminae on a very fine scale. Nodules in this type of matrix are surrounded by drape structures, implying that they are primary or early diagenetic (Figures 1, 2, page 86). Some details of the draping show that the nodules formed either at the surface of deposition or else grew in the soft iron oxides as concretions.

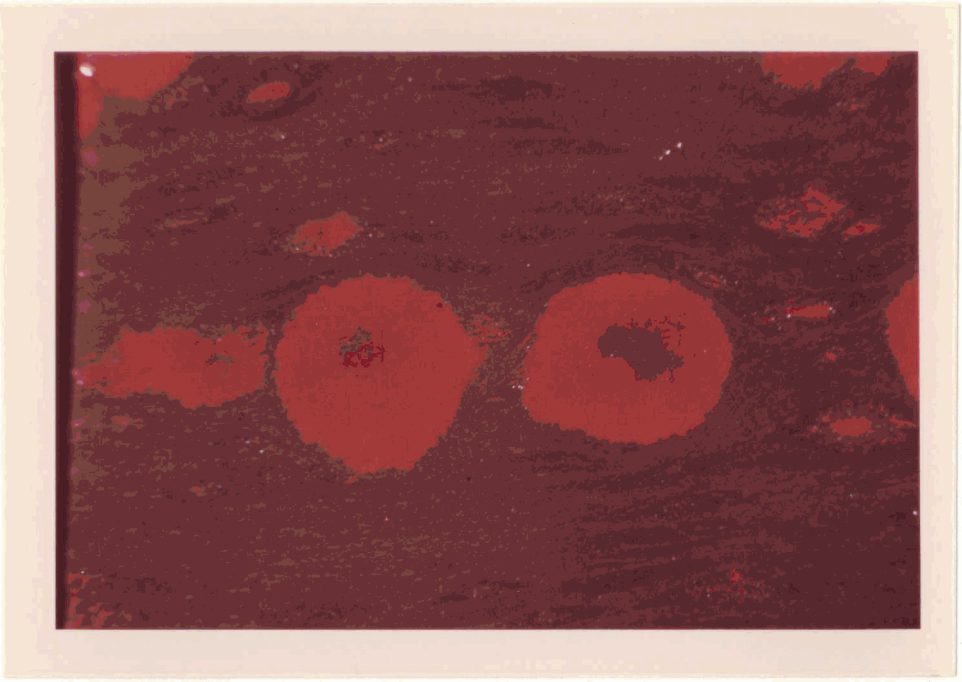


Figure 1

Polished section microphotograph, X45: Primary or early diagenetic red jasper nodules in laminated hematite. Laminae between the nodules dip towards the left so as to pass beneath nodules in that direction, indicating that the nodules are at successfully higher horizons to the left, in the limited interval in which they occur. Oblique illumination.

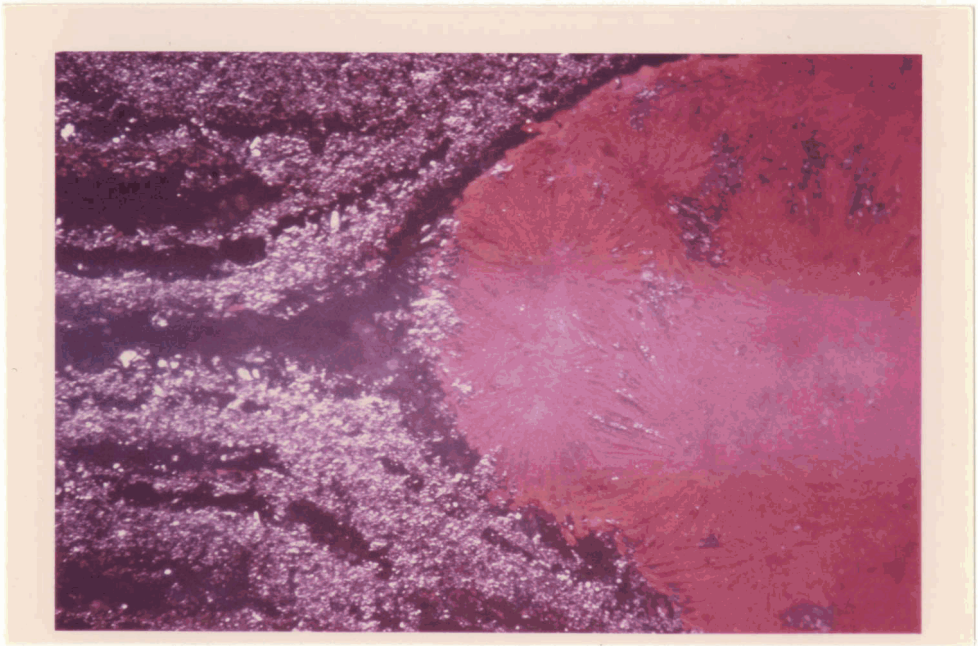


Figure 2

Polished section photomicrograph, X45: Compound spherulitic siliceous nodule in laminated hematite with pronounced draping. Note bent crystalline needles at contact, upper right. Oblique illumination.

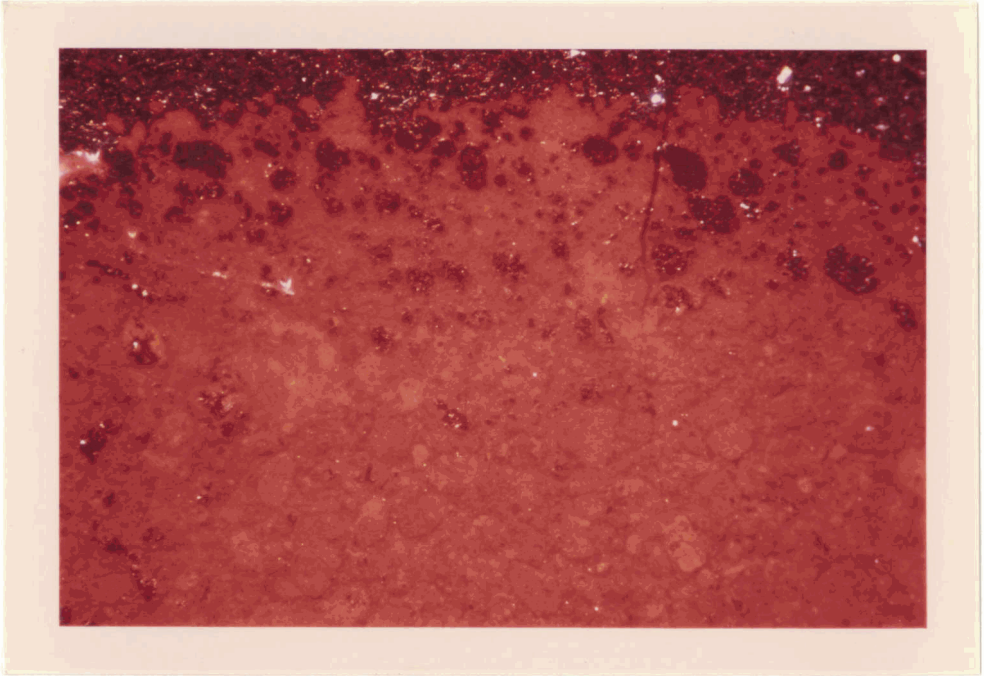


Figure 1

Polished section photomicrograph, X45: Contact of granular red jasper lens with hematite showing selective replacement of granules by hematite. Oblique illumination.

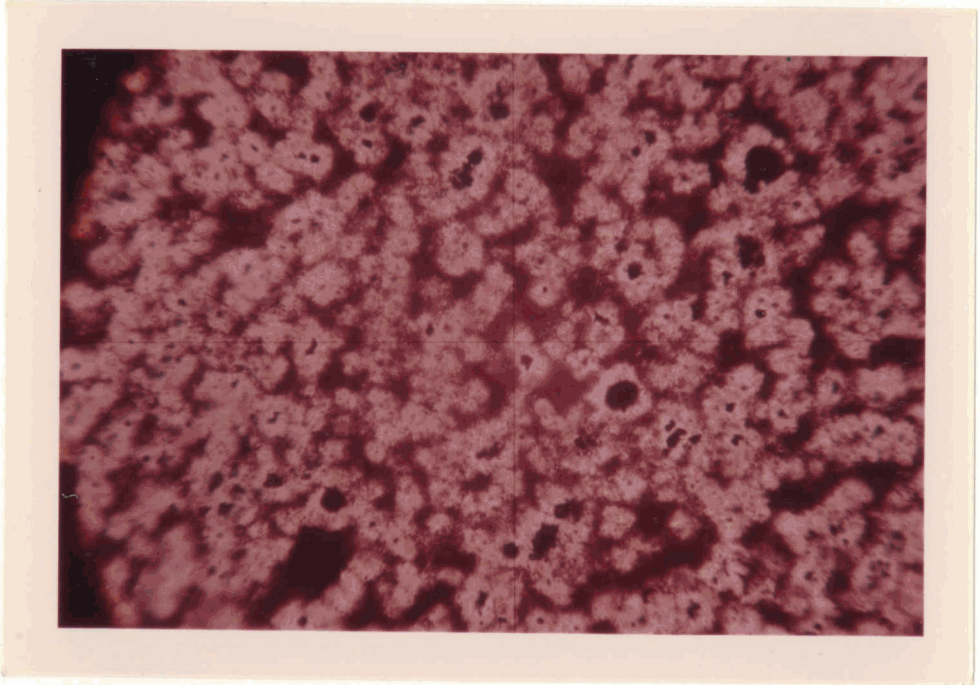


Figure 2

Thin section photomicrograph, X440: Microspherulitic jasper; opaque cores of spherulites are hematite. Plane light.

The oval nodules are usually zoned in concentric layers of differing colour and composition. Red jasper, petrographically the same as that of the banded ores, usually forms the outermost or next to outermost layer. Jasper of the cloudy granular type is the most common, but microspherulitic and microbotryoidal varieties are also present.

Occasionally the ore contains elongate masses of red jasper and pink spherulitic silica that obviously are similar to the more equidimensional varieties of nodule, differing only in shape. However, in many parts of the iron formation there are lenses that are not related to nodules. In this class are small wispy lenses of maroon jasper, clastic sediment or fine grained dolomite that originally were part of a thin bed that has been stretched by compaction processes (Figure 1, page 79). Also belonging here are the oblong-rectangular pieces of red and maroon jasper that are obviously fragments of a thin jasper bed that has been pulled apart.

The nodules have been replaced to all degrees by hematite, from the production of slight irregularities along the borders due to incipient replacement to complete change to hematite (Figures 1, 2, page 89). The replacing hematite is usually more coarsely crystalline than the surrounding hematite (producing long blades in cross section), and this causes the replaced nodules to be visible as ghost structures even after complete replacement (Figure 2, page 89). In some nodules there is partial replacement along concentric zones; in others the change has extended along a narrow radial trend from the exterior of the centre, where it becomes more widespread, producing a central mass of hematite (Figure 2, page 89).

C. Complex Ores

Complex ores are composed of hematite and gangue arranged in intricate patterns (Figures 1, 2, page 90, Figures 1, 2, page 91). The complex texture appears to be due to successive partial replacement by the various gangue minerals and finally by hematite. The clearest examples of the sequence of change involve the conversion of a laminated dolomite-hematite ore into a complex ore. The first step, after compaction and flowage had stretched and folded the carbonate laminae (Figure 1, page 79), was replacement of the carbonate by red jasper. The red jasper was then converted to maroon jasper, which finally was partly replaced by hematite, accompanied by the development of secondary red jasper borders of the type shown in Figure 2, page 92.

Other complex ores do not reveal any relict structures traceable to carbonate laminae, and therefore the parent material and the sequence of change were presumably different. Figures 1, 2, page 90, Figure 1, page 91 illustrate two types of these complex ores. In Figures 1, 2, page 90,



Figure 1

Polished section photomicrograph, X10: Cored nodules of red jasper with zonal replacement by hematite. Nodules in upper part of photo have been fractured and infilled with sparry dolomite and plastic hematite. Some nodules have narrow, discontinuous fringes of radially arranged acicular pseudomorphic crystals, now quartz. Oblique illumination.



Figure 2

Polished section photomicrograph, X10: Red jasper nodules partly replaced by hematite. Oblique illumination.

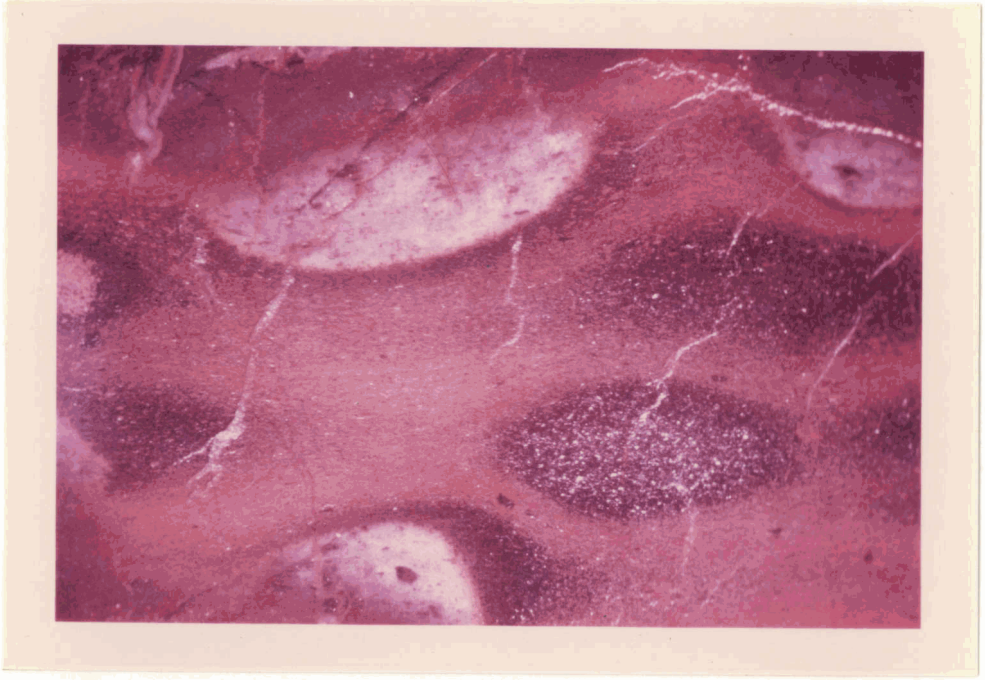


Figure 1

Polished section photomicrograph, X10: Opalescent white siliceous nodules in replacement front, some totally replaced by hematite (right of centre) and others partly replaced (lower left). Oblique illumination.

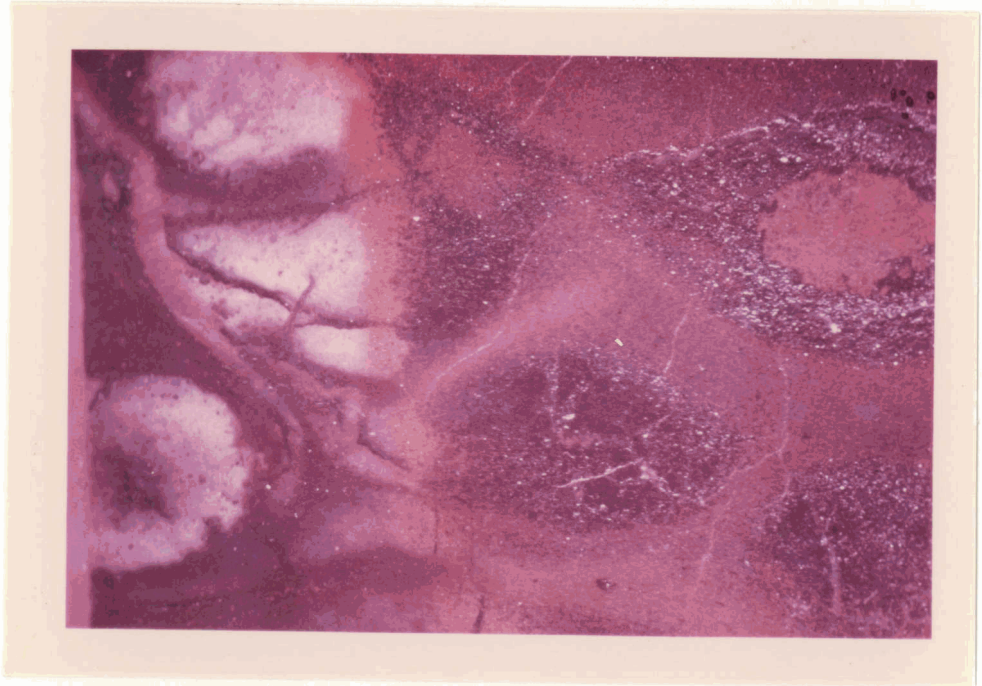


Figure 2

Polished section photomicrograph, X10: Similar to above figure; white nodules partly replaced by hematite at replacement front. Oblique illumination.

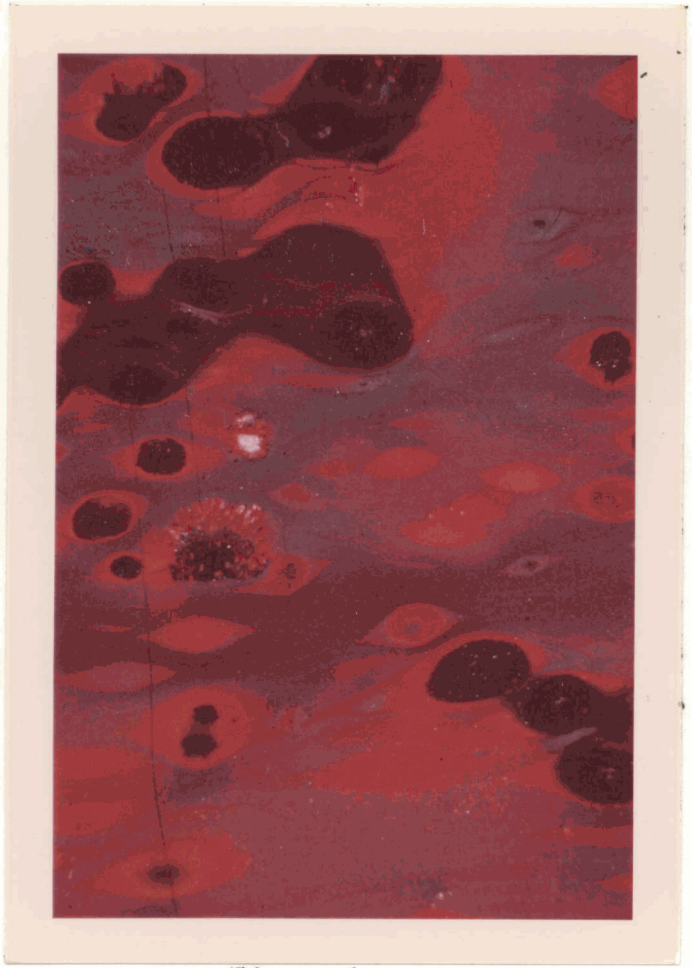


Figure 1

Polished section photograph, X3.5: Complex ore, the product of a series of alterations. No primary material remains. The dark siliceous nodules are earliest; they have been partly to completely jasperized to secondary red jasper, which in turn has been party to completely replaced by hematite. Oblique illumination.

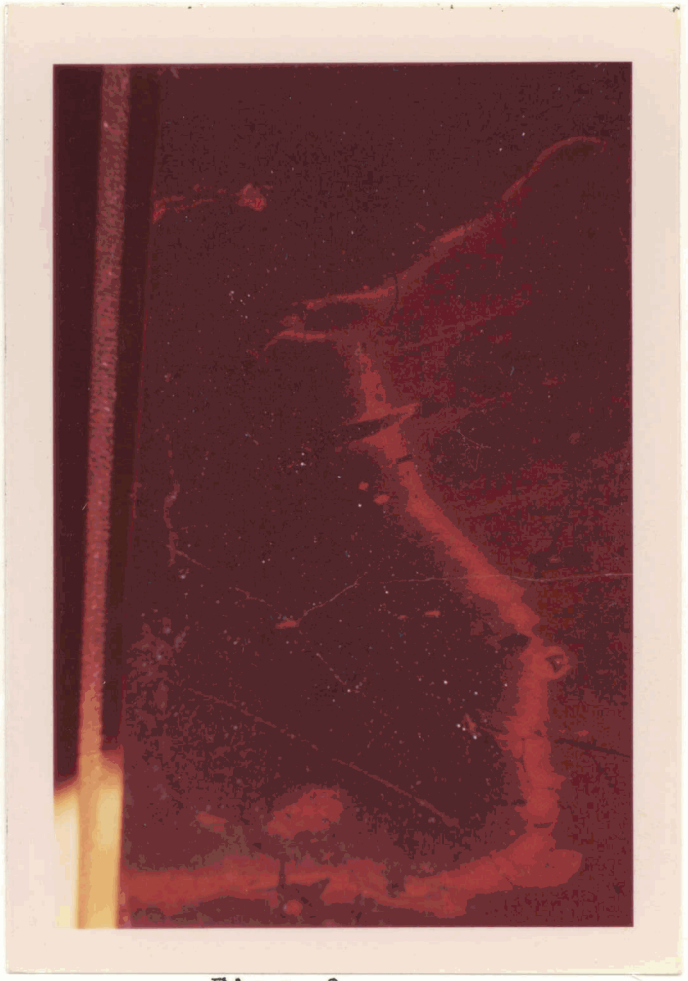


Figure 2

Polished section photograph, X6: Hematite (left); dark reddish jasper-like silica (right) along replacement front marked by narrow zone of secondary red jasper. Oblique illumination.

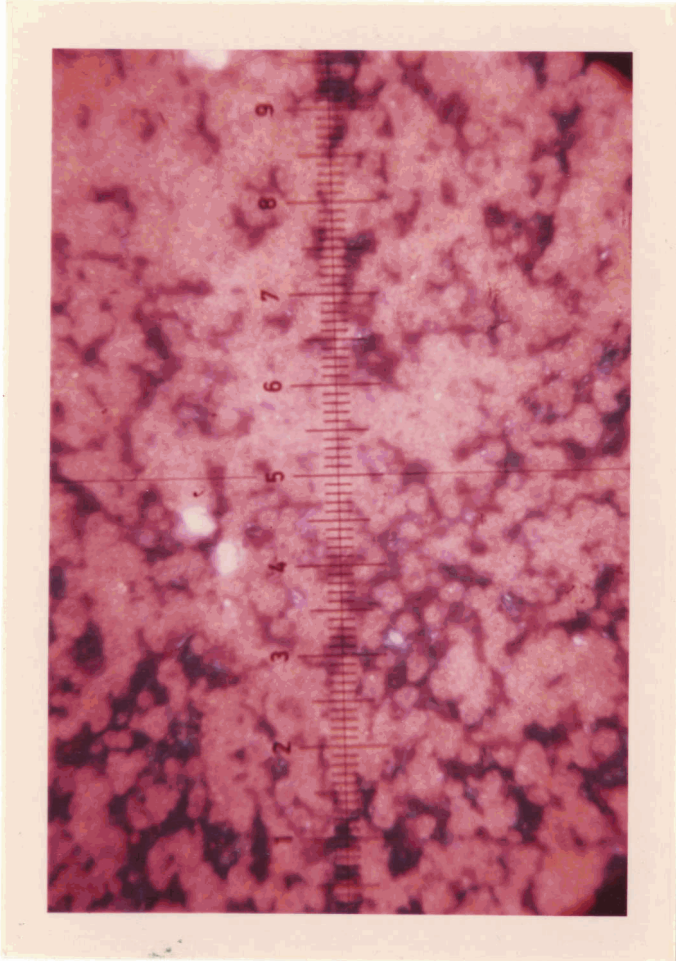


Figure 1
Polished section photomicrograph, X180: Detail of secondary red jasper zone of Figure 2, page 91 showing clusters of rounded jasper granules and intergranular hematite (dark). Crossed nicols.

white siliceous nodules have been replaced by specular hematite, while the surrounding dark siliceous matrix has been converted to secondary red jasper. The original siliceous material may have been maroon jasper in which nodules were absent but which developed before replacement by hematite. The ore shown in Figure 1, page 91, is more complex than the preceding ore, since all that remains of the host rock are blackish siliceous nodules and these are partly converted to nodules of secondary red jasper. The red nodules in turn are partly replaced by hematite.

Some complex ore is less spectacular in texture than those just described but nevertheless has had an involved history of development. The ore illustrated in Figure 2, page 91, may have been red jasper originally, which was converted to maroon jasper by recrystallization, and finally to hematite by replacement.

Chemical Constitution of the Iron Formation

Principal Constituents

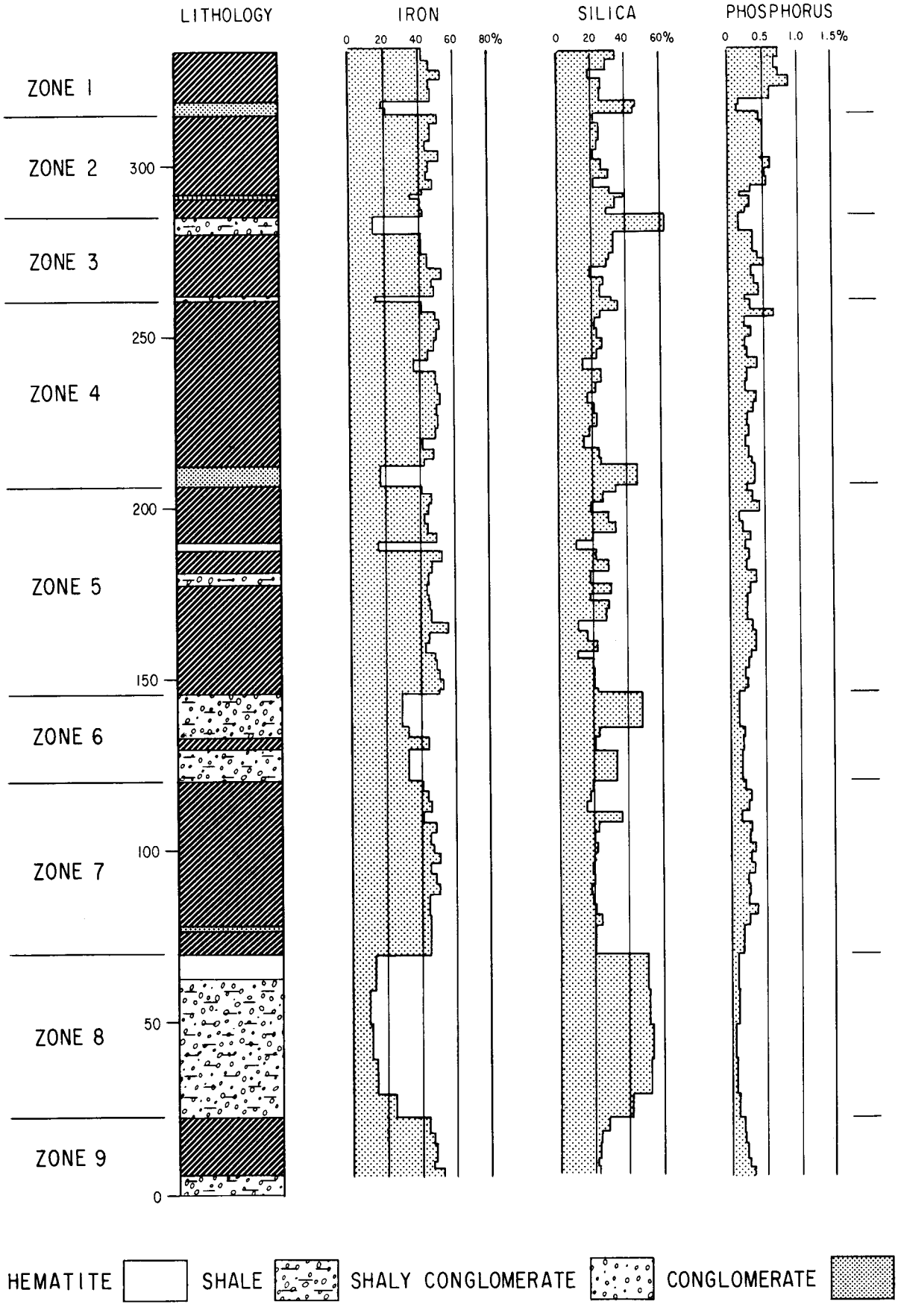
From an economic point of view the principal chemical components of the ore are the iron, the phosphorus and the insolubles. In the early part of the assay program samples were taken over short intervals so that each sample represented only one bed or, if their lithologies were very similar, one small group of beds. The object of this was to determine how much chemical variation there was between different beds and zones within the ore body. The results of the detail assays on IF-219-63 are shown in chart form (page 94). From this it is evident that the iron content of the ore part of the section is between 40% and 50% and of the waste 10% to 20%. The silica in the ore is ordinarily 20% and in the clastic waste 40% to 50%. The phosphorus content is high in the upper zones of the iron formation but diminishes downward from a high of 0.75% to approximately 0.25%. The following tabulation illustrates the range of average phosphorus values for the various zones of iron formation within the main ore zone.

Zone	% Phosphorus	
	Range	Average
1	0.46 - 0.86	0.68
2	0.38 - 0.65	0.52
3	0.31 - 0.52	0.40
4	0.29 - 0.46	0.37
5	0.27 - 0.44	0.32
7	0.21 - 0.33	0.25
9	0.15 - 0.28	0.22

The clastic horizons contain relatively little phosphorus, generally less than 0.20%. On page 116a similar chart of the chemical constitution of samples from diamond drill hole Y-15 shows the same pattern of iron, silica and phosphorus distribution.

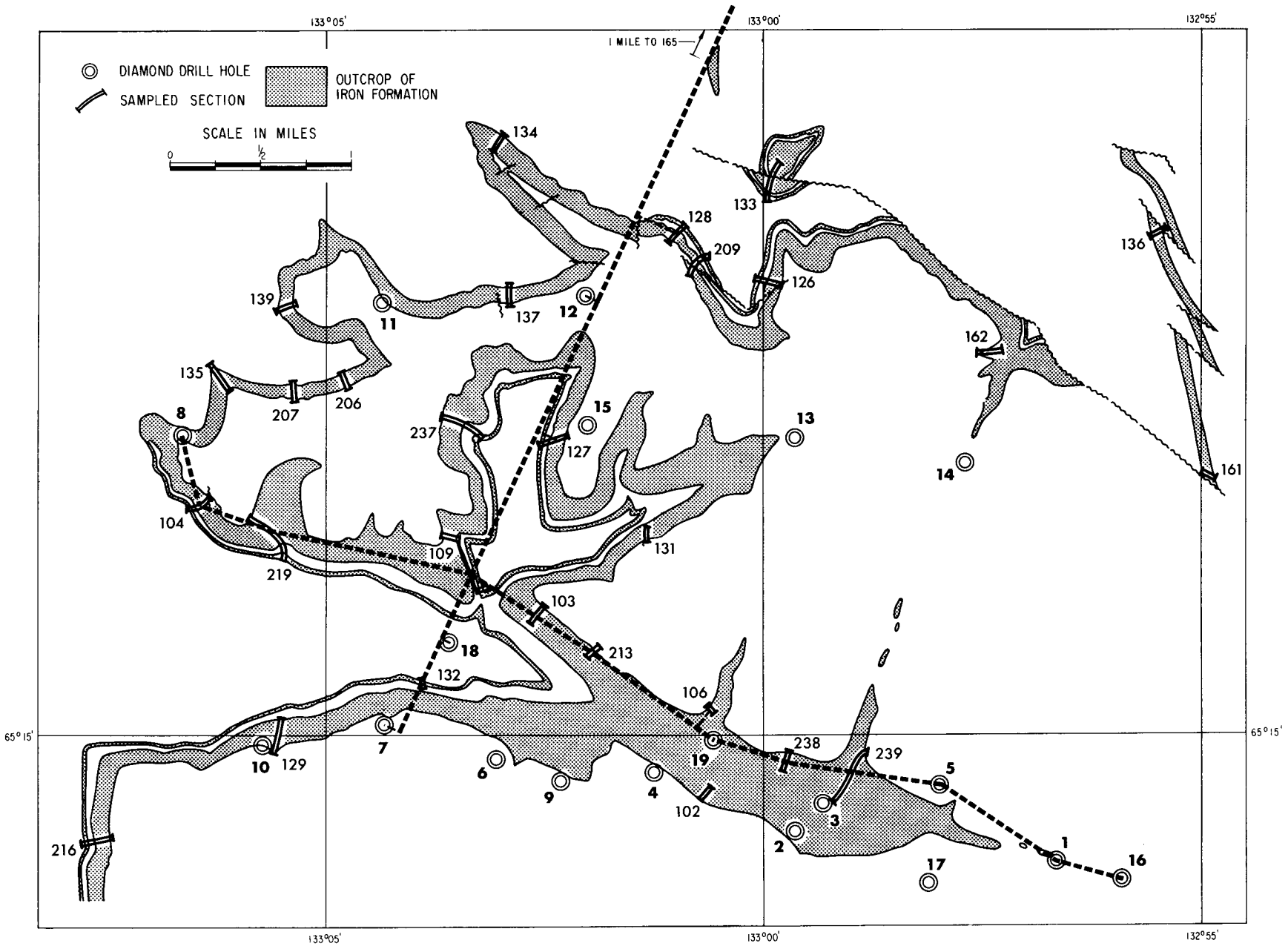
TYPICAL CHANNEL SAMPLE LOG SHOWING CHEMICAL COMPOSITION

IF 219 - 63

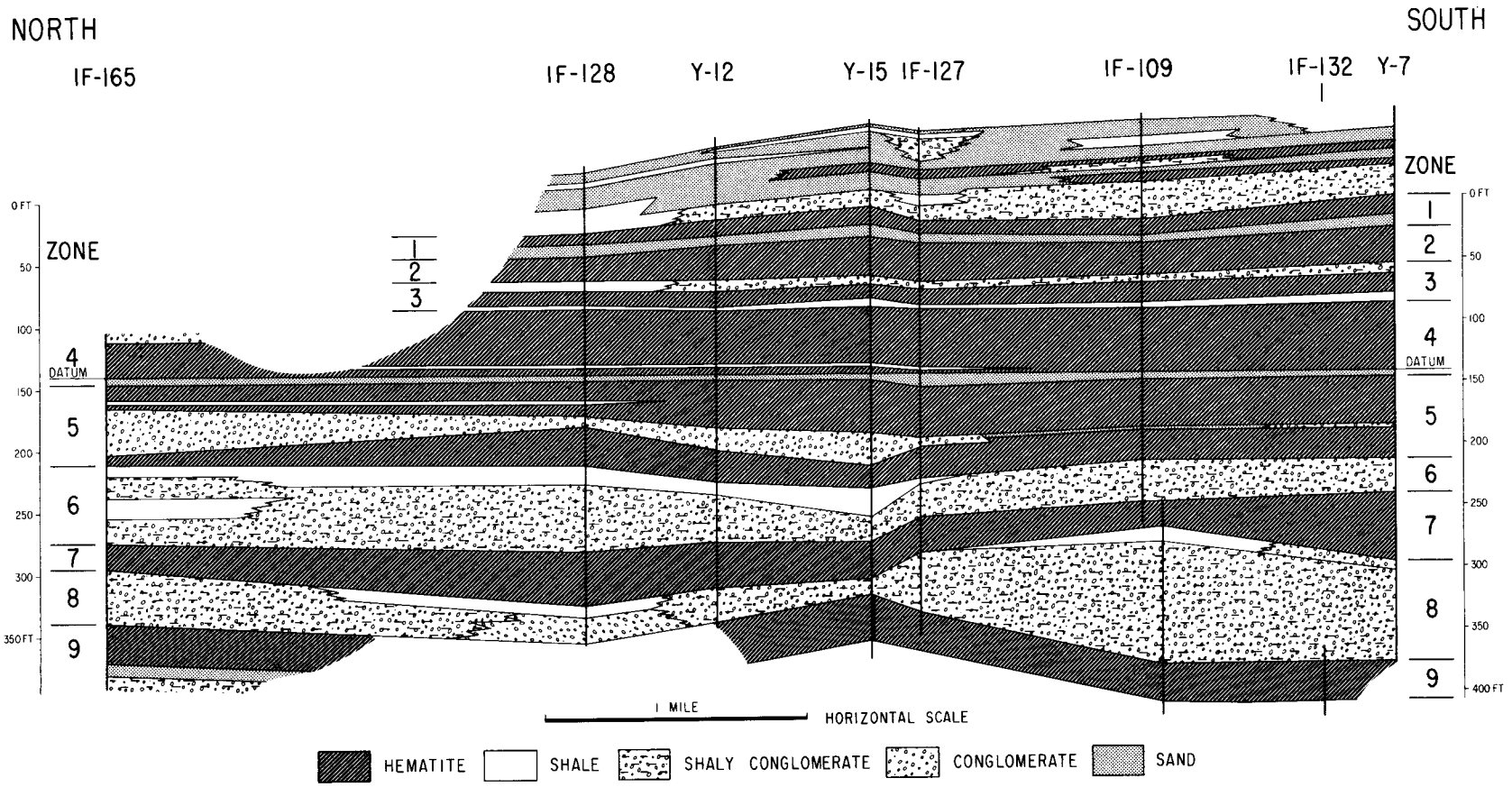


The two assay charts illustrate that the quality of the ore is quite consistent and that there is not a greal deal of vertical variation, particularly in the iron and silica content. In order to display the horizontal variations, two cross sections are presented with attendant tables which show the thickness and average iron, phosphorus and insoluble content at each control point. By following the horizontal column the reader can see the changes are from one point to another within one specific ore horizon. It should be borne in mind that these figures are based upon minimum thicknesses of five feet so that iron formation assays are occasionally altered by the inclusion of thin waste bands and vice versa. Even so, these figures show that the ore horizons are quite consistent throughout this part of the Iron Creek block. This consistency of constitution is what would be expected from unaltered sedimentary horizons.

IRON CREEK AREA
LOCATION MAP OF STRATIGRAPHIC CROSS SECTIONS



NORTH - SOUTH
STRATIGRAPHIC CROSS SECTION
IRON CREEK ORE ZONE



ORE

WEIGHTED AVERAGE CHEMICAL ANALYSES NORTH-SOUTH STRATIGRAPHIC SECTION *

Zone		IF-165 Ft.	IF-165 %	IF-128 Ft.	IF-128 %	Y-12 Ft.	Y-12 %	Y-15 Ft.	Y-15 %	IF-127 Ft.	IF-127 %	IF-109 Ft.	IF-109 %	IF-132 Ft.	IF-132 %	Y-7 Ft.	Y-7 %	Average Ore (Wt'd) Ft.	Average Ore (Wt'd) %	Average Composited Ore & Waste (wt'd) Ft.	Average Composited Ore & Waste (wt'd) %
**	Fe				37.42				37.07										37.24		23.23
	P.	N.S.		7.5	0.64	N.A.		8.3	0.82	N.A.		X		N.S.		X		7.9	0.73	56.7	0.53
	Insol.				39.4				38.0										38.7		48.5
1	Fe				48.09		38.23		39.42		44.05		42.73				40.46		42.08		31.73
	P.	N.S.		9.5	0.72	8.0	0.67	12.7	0.65	10.5	0.82	13.0	0.81	N.S.		13.3	0.69	11.2	0.73	20.1	0.52
	Insol.				25.1		35.8		32.4		29.0		31.8				32.3		31.1		39.6
2	Fe				47.23		41.98		43.72		47.23		46.13				44.89		45.11		45.11
	P.	N.S.		20.0	0.51	28.3	0.50	29.0	0.53	31.0	0.54	26.5	0.38	N.S.		24.2	0.53	26.5	0.50	26.5	0.50
	Insol.				26.5		31.0		26.6		26.0		26.6				26.1		27.2		27.2
3	Fe				41.50		40.17		45.13		42.84		41.47				40.77		42.00		35.80
	P.	N.S.		22.0	0.34	14.1	0.37	19.2	0.55	16.5	0.42	19.0	0.39	N.S.		21.4	0.44	18.7	0.42	25.6	0.37
	Insol.				30.8		35.6		24.6		32.1		30.8				31.1		30.6		35.7
4	Fe		46.59		45.32		43.93		43.49		44.84		47.14				42.81		44.71		41.18
	P.	28.5	0.30	53.5	0.37	56.6	0.35	54.6	0.37	52.0	0.38	51.0	0.37	N.S.		49.3	0.36	49.2	0.36	56.1	0.34
	Insol.		27.1		23.5		26.9		25.8		27.6		22.4				24.4		25.3		28.2
5	Fe		39.57		41.77		42.27		44.00		44.15		45.38				41.65		42.99		34.48
	P.	27	0.34	68.0	0.33	56.0	0.33	58.5	0.35	65.5	0.31	65.5	0.35	N.S.		56.5	0.32	56.7	0.33	81.8	0.27
	Insol.		32.1		26.3		26.6		24.6		25.4		24.8				24.1		25.8		26.8
6	Fe																				21.61
	P.	X		X		X		X		X		X		N.S.		X		X		42.5	0.21
	Insol.																				43.3
7	Fe	⊕			47.71		46.57		42.03		46.83		46.15				44.12		45.60		45.60
	P.	21.0	N.S.	39.0	0.27	35.8	0.26	30.8	0.27	36.0	0.26	28.0	0.23	N.S.		44.8	0.23	33.6	0.25	33.6	0.25
	Insol.				20.1		25.2		30.5		26.9		24.0				24.3		25.0		25.0
8	Fe																				13.09
	P.	X		X		X		X		X		X		N.S.		X		X		51.3	0.12
	Insol.																				55.0
9	Fe		46.27	⊕		⊕			44.70		41.27		42.36		45.87	⊕			44.16		44.16
	P.	31.5	0.23	31.5	N.S.	31.5	N.S.	31.5	0.24	31.5	0.18	31.5	0.23	38.0	0.27	31.5	N.S.	32.8	0.23	32.8	0.23
	Insol.		25.9						24.0		32.1		29.9		24.2				26.9		26.9
1-9	Fe		44.55		44.48		43.30		43.53		44.62		45.07				42.86		44.03		33.62
Total	P.	108	0.28	243.5	0.35	230.3	0.35	236.3	0.38	243.0	0.36	234.5	0.36			241.0	0.35	228.7	0.36	370.3	0.29
	Insol.		27.6		25.1		27.9		26.2		27.6		25.9				25.9		26.5		33.8

N.S. - No sample
N.A. - Not analyzed

* Reserve calculation criteria used to differentiate ore & waste and assign thicknesses.
** Undesignated zone above the main iron formation with iron values occurring chiefly in hematitic sandstone.
⊕ Est. thickness & average zone grade used for wt'd. average section or hole calculation
⊕⊕ Incomplete sample - thickness modified or omitted from weighted zone averages.

WASTE

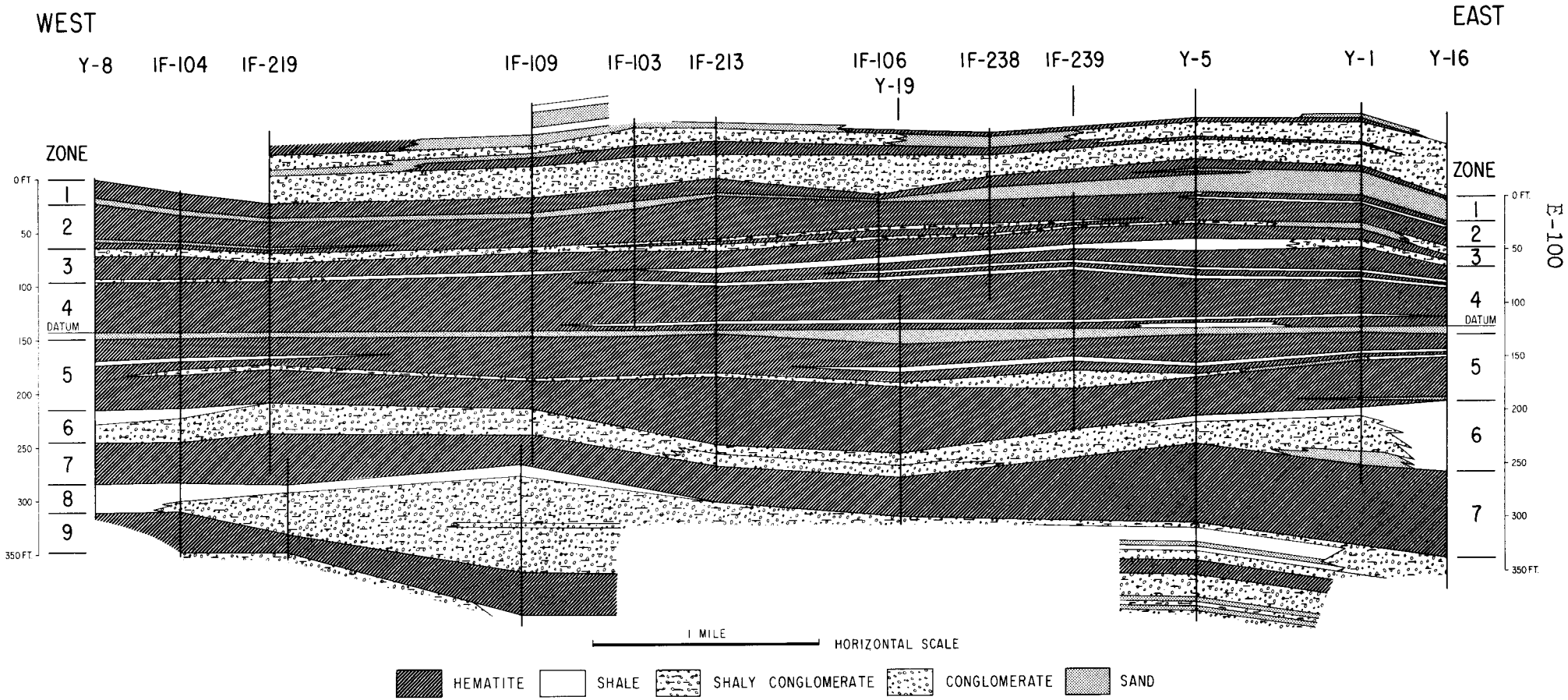
WEIGHTED AVERAGE CHEMICAL ANALYSES NORTH-SOUTH STRATIGRAPHIC SECTION *

Zone		IF-165 Ft.	IF-165 %	IF-128 Ft.	IF-128 %	Y-12 Ft.	Y-12 %	Y-15 Ft.	Y-15 %	IF-127 Ft.	IF-127 %	IF-109 Ft.	IF-109 %	IF-132 Ft.	IF-132 %	Y-7 Ft.	Y-7 %	Wt'd. Averages Waste Ft.	Wt'd. Averages Waste %
**	Fe				20.68				19.39				21.83				20.93		20.96
	P.	N.S.		20.0	0.37	N.A.		43.1	0.49	N.A.		86.0	0.52	N.S.		46.0	0.52	48.8	.50
	Insol.				51.3				51.5				47.8				52.5		50.1
1	Fe				16.17		23.74		15.79		20.34		19.80				15.33		18.70
	P.	N.S.		9.5	0.17	12.5	0.42	9.1	0.18	7.0	0.24	6.0	0.25	N.S.		9.1	0.20	8.9	0.25
	Insol.				53.3		48.5		50.6		48.1		46.6				51.9		50.4
2	Fe																		
	P.	N.S.		X		X		X		X		X		N.S.		X		X	
	Insol.																		
3	Fe						8.68		23.24		16.15		26.60				24.77		18.99
	P.	N.S.		X		9.4	0.26	5.7	0.29	6.0	0.13	7.0	0.22	N.S.		6.3	0.26	6.9	0.23
	Insol.						63.4		31.3		53.4		47.6				43.9		49.5
4	Fe		18.91		14.16						14.03		18.56						16.02
	P.	5.5	0.17	5.0	0.20	X		X		11.0	0.17	6.0	0.24	N.S.		X		6.9	0.19
	Insol.		47.0		47.2						51.9		45.6						48.7
5	Fe						20.32		12.37		8.72								15.26
	P.	38.0	N.S.	X		26.8	0.15	26.6	0.13	9.0	0.12	X		N.S.		X		25.1	0.14
	Insol.						32.9		26.8		23.0								28.9
6	Fe				23.24		19.29		20.04		20.13		25.39				21.99		21.61
	P.	64.0	N.S.	69.0	0.27	47.6	0.18	43.0	0.19	26.0	0.23	25.0	0.18	N.S.		23.0	0.16	42.5	0.21
	Insol.				37.0		48.9		47.0		41.6		44.8				44.3		43.3
7	Fe																		
	P.	X		X		X		X		X		X		N.S.		X		X	
	Insol.																		
8	Fe			⊕		⊕⊕	30.94		28.75		16.17		10.09			⊕			13.09
	P.	44.0	N.S.	18.0	N.S.	3.0	0.14	11.8	0.23	45.5	0.13	108.5	0.10	N.S.		80.0	N.S.	51.3	0.12
	Insol.						29.9		33.1		54.2		57.7				N.A.		55.0
9	Fe																		
	P.	X		N.S.		N.S.		X		X		X		X		N.S.		X	
	Insol.																		
1-9	Fe				20.33		19.48		18.77		16.57		14.07				15.61		16 71
	P.			101.5	0.23	99.3	0.21	96.2	0.18	104.5	0.17	152.5	0.13			118.4	0.14	141.6	0.17
Total	Insol.				42.2		45.3		39.1		47.7		54.2				52.1		46.0

N.S. - No sample
N.A. - Not analyzed

* Reserve calculation criteria used to differentiate ore & waste and assign thicknesses.
** Undesignated zone above the main iron formation with iron values occurring chiefly in hematitic sandstone.
⊕ Est. thickness & average zone grade used for wt'd. average section or hole calculation.
⊕⊕ Incomplete sample - thickness modified or omitted from weighted zone averages.

EAST – WEST
STRATIGRAPHIC CROSS SECTION
IRON CREEK ORE ZONE



ORE

WEIGHTED AVERAGE CHEMICAL ANALYSES EAST-WEST STRATIGRAPHIC SECTION *

Zone	Y-8 Ft.	Y-8 %	IF-104 Ft.	IF-104 %	IF-219 Ft.	IF-219 %	IF-109 Ft.	IF-109 %	IF-103 Ft.	IF-103 %	IF-213 Ft.	IF-213 %	IF-106 Y-19 Ft.	IF-106 Y-19 %	IF-238 Ft.	IF-238 %	IF-239 Ft.	IF-239 %	Y-5 Ft.	Y-5 %	Y-1 Ft.	Y-1 %	Y-16 Ft.	Y-16 %	Weighted Averages Ore Ft.	Weighted Averages Ore %	Weighted Averages Ore & Waste Ft.	Weighted Averages Ore & Waste %
** Fe										36.89						38.67										37.56		25.21
P.	N.S.		N.S.		X		X		10.0	0.77	X		N.S.		6.0	1.25	N.S.		X		X		X		8.0	0.95	39.0	0.62
Insol.										39.8						30.7										36.4		44.2
Fe		42.94		43.87		40.75		42.73		43.78		38.91		42.76		43.86				43.14	⊕					42.53		29.78
1 P.	15.4	0.60	16.0	0.71	19.	0.62	13.0	0.81	13.0	0.86	11.0	0.87	5.5	0.46	16.0	0.90	N.S.		7.7	0.77	5.5	N.A.	X		12.2	0.74	23.9	0.47
Insol.		28.6		28.8		32.2		31.8		29.6		29.9		28.2		26.6				26.9						29.4		40.0
Fe		40.96		41.02		44.15		46.13		45.98		46.47		46.47		43.32		46.79		43.93		42.39		43.18		44.22		38.24
2 P.	26.8	0.43	31.0	0.45	29.0	0.46	26.5	0.38	31.0	0.55	32.0	0.59	24.5	0.57	24.0	0.52	20.5	.55	27.0	0.60	24.1	0.64	22.3	0.65	26.6	0.53	37.6	0.44
Insol.		30.2		30.7		27.6		26.6		26.6		25.8		25.5		29.1		26.3		24.9		27.8		28.6		27.4		31.1
Fe		41.34		46.52		44.21		41.47		40.99		44.96		40.24		40.91		43.09		38.68		41.37		46.74		42.18		35.53
3 P.	22.4	0.37	23.0	0.40	20.0	0.39	19.0	0.39	27.5	0.37	15.5	0.45	28.0	0.43	17.5	0.35	17.5	0.44	22.1	0.50	9.8	0.52	5.9	0.50	19.0	0.42	27.9	0.37
Insol.		26.4		26.7		28.7		30.8		31.1		30.7		29.3		30.0		29.6		30.6		31.2		24.5		29.3		36.1
Fe		46.55		46.49		46.99		47.14		45.47		43.06		41.03		47.04		45.82		42.90		43.20		43.79		44.79		40.46
4 P.	39.3	0.34	48.0	0.31	48.0	0.31	51.0	0.37	47.0	0.34	56.0	.40	50.0	0.39	27.0	0.36	74.0	.34	64.4	0.42	58.0	0.40	48.6	0.46	50.9	0.37	60.4	0.35
Insol.		22.9		24.2		23.9		22.4		25.6		24.7		26.3		27.9		23.9		24.9		27.6		26.4		24.9		27.9
Fe		41.99		42.83		45.81		45.38				41.62		40.72				46.27		44.44		43.27		43.08		43.32		40.68
5 P.	62.1	0.29	65.5	0.27	60.0	0.28	65.5	0.35	N.S.		103.0	0.29	99.5	0.30	N.S.		69.0	0.31	67.6	0.44	70.2	0.36	58.4	0.38	72.1	0.32	79.6	0.30
Insol.		24.1		25.7		24.2		24.8				27.4		27.3				30.5		23.1		25.9		25.9		26.0		26.9
Fe				54.99		38.13								33.83								37.16				39.65		22.2
6 P.	X		4.5	0.32	10.5	0.20	X		N.S.		X		5.9	0.22	N.S.		N.S.		X		7.5	0.14	X		7.1	0.21	35.1	0.16
Insol.				10.1		23.2								28.3								37.6				26.0		45.9
Fe		44.06		46.87		45.18		46.15						41.34						42.79	⊕	42.47		43.10		43.70		43.70
7 P.	37.3	0.25	35.0	0.28	64.0	0.24	28.0	0.23	N.S.		N.S.		36.6	0.26	N.S.		N.S.		72.7	0.24	71.0	0.32	81.4	0.25	53.3	0.26	53.3	0.26
Insol.		23.2		21.4		23.9		24.0						24.7						23.6		28.7		23.6		24.4		24.4
Fe																												10.70
8 P.	X		X		X		X		N.S.		N.S.		N.S.		N.S.		N.S.		X		N.S.		N.S.				45.1	0.11
Insol.																												54.3
Fe				44.48		45.06		42.36	(Omit Zone 9 from Calculations)											37.77						43.06		43.06
9 P.	N.S.		39.5	0.19	16.5	0.22	31.5	0.23	N.S.		N.S.		N.S.		N.S.		N.S.		12.7	0.28	N.S.		N.S.		25.1	0.22	25.1	0.22
Insol.				25.6		25.9		29.9												31.6						27.8		27.8
Fe									ORE - TOTAL FOOTAGES & WEIGHTED AVERAGE GRADES																			
1- Fe		43.12		42.78		44.85		45.49						41.26						43.02		42.66		43.36		43.38		
8 P.	203.3	0.34	223.0	0.35	250.5	0.33	203.0	0.38					250.0	0.35					261.5	0.41	246.1	0.39	216.6	0.38		0.39		
Insol.		25.1		25.4		25.4		25.3						26.8						24.6		27.9		25.4	249.2	26.3		
ORE & WASTE- TOTAL FOOTAGES & WEIGHTED AVERAGE GRADES																												
1- Fe		36.04		36.90		38.17		30.03						34.28						34.92		33.10		30.82				33.34
8 P.	292.2	0.29	297.0	0.31	335.	0.29	441.5	0.32					337.4	0.29					352.2	0.35	377.9	0.32	367.4	0.28			401.9	0.33
Insol.		31.1		31.5		31.4		39.7						32.5						31.6		36.5		37.7				34.9

N.A. - Not analyzed
N.S. - Not sample

* Reserve calculation criteria used to differentiate ore & waste and assign thickness.

** Undesignated zone above the main iron formation with iron values occurring chiefly in hematitic sandstone.

⊕ Est. thickness & average zone grade used for wt'd. section or hole calculation.

WASTE

WEIGHTED AVERAGE CHEMICAL ANALYSES EAST-WEST STRATIGRAPHIC SECTION*

Zone	Y-8 Ft.	Y-8 %	IF-104 Ft.	IF-104 %	IF-219 Ft.	IF-219 %	IF-109 Ft.	IF-109 %	IF-103 Ft.	IF-103 %	IF-213 Ft.	IF-213 %	IF-106 Y-19 Ft.	IF-106 Y-19 %	IF-238 Ft.	IF-238 %	IF-239 Ft.	IF-239 %	Y-5 Ft.	Y-5 %	Y-1 Ft.	Y-1 %	Y-16 Ft.	Y-16 %	Weighted Average Ft.	Weighted Average %
Fe						33.50		21.83		20.00		20.12														22.03
** P.	N.S.		N.S.		7.0	0.51	86.0	0.52	28.0	0.60	3.0	0.44	N.S.		N.S.		N.S.		N.A.		N.A.		N.A.	31.0	0.54
Insol.						43.6		47.8		42.0		45.5														46.2
Fe		22.48		22.37				19.80		19.55						15.53				13.93	⊕			14.42		16.48
1 P.	4.7	0.21	5.0	0.26	X		6.0	0.25	8.0	0.17	X		X		5.5	0.22	N.S.		20.6	0.22	22.0	N.A.	21.7	0.13	11.7	0.19
Insol.		45.8		44.8				46.6		50.2						53.3				54.1				52.0		51.1
Fe		29.00										14.69														23.77
2 P.	13.9	0.22		X	X		X		X		8.0	0.22	X		X		X		X		X		X		11.0	0.22
Insol.		41.6										37.6														40.1
Fe		11.65		13.00		12.45		26.60				20.05		28.11				32.31		21.00		24.78		19.55		21.34
3 P.	7.2	0.19	7.0	0.16	5.0	0.16	7.0	0.22	X		16.5	0.23	6.0	0.12	X		8.5	0.35	5.5	0.31	14.0	0.36	12.7	0.32	8.9	0.26
Insol.		60.8		62.0		60.4		47.6				43.8		36.7				39.7		59.8		48.9		57.1		50.6
Fe		18.50		8.00		17.85		18.56						15.27				11.96		13.51		24.57		19.99		17.23
4 P.	7.9	0.24	6.0	0.13	6.0	0.20	6.0	0.24	X		X		13.9	0.17	X		10.0	0.12	8.2	0.25	15.0	0.36	12.2	0.24	9.5	0.23
Insol.		42.4		52.0		47.2		45.6						42.7				52.8		43.9		37.7		38.5		43.7
Fe														29.06				7.72						18.59		15.27
5 P.	X		X		X		X		N.S.		X		6.4	0.16	N.S.		13.0	0.11	X		X		3.0	0.21	7.5	0.14
Insol.														44.9				34.9						17.7		35.5
Fe		26.10		29.89		26.49		25.39						13.41						11.59		12.20		10.54		17.80
6 P.	28.2	0.22	29.0	0.19	19.5	0.17	25.0	0.18	N.S.		20.0	N.A.	11.1	0.15	N.S.		N.S.		25.4	0.17	45.8	0.12	66.2	0.10	28.0	0.15
Insol.		33.3		41.3		42.6		44.8						39.8						58.8		57.8		61.4		50.9
Fe																										
7 P.	X		X		X		X		N.S.		N.S.		X		N.S.		N.S.		X		X		X		X	
Insol.																										
Fe	⊕			11.80		13.40		10.09					⊕							7.82	⊕		⊕			10.70
8 P.	27.0	N.A.	27.0	0.13	47.0	0.10	108.5	0.10	N.S.		N.S.		50.0	N.S.	N.S.		N.S.		31.0	0.13	35.0	N.S.	35.0	N.S.	45.1	0.11
Insol.				56.0		51.5		57.7												45.2						54.3
Fe									(Omit Zone 9 from calculations)																	
9 P.	N.S.		X		X		X		N.S.		N.S.		N.S.		N.S.		N.S.		X		N.S.		N.S.		X	
Insol.																										
WASTE - TOTAL FOOTAGES & WEIGHTED AVERAGE GRADES																										
1- Fe		19.84		19.81		18.35		16.87						14.31						11.58		15.26		12.82		16.93
8 P.	88.9	0.19	74.0	0.17	84.5	0.16	238.5	0.27					87.4	0.13					90.7	0.18	131.8	0.18	150.8	0.14	15.27	0.24
Insol.		44.7		49.7		49.0		51.9						48.7						51.8		52.5		55.3		49.0

N.S. - No sample
N.A. - Not analyzed

* Reserve calculation criteria used to differentiate ore & waste and assign thicknesses.
** Undesignated zone above the main iron formation with iron values occurring chiefly in hematitic sandstone.
⊕ Est. thickness & average zone grade used for wt'd. average section or hole calculation.

Relationships Between Principal Constituents

In an attempt to investigate the mutual relationships between the constituents of the ore, a number of plots were made from the type of data presented in the foregoing tabulation. Each plotted point represents the average assay for one ore zone at a specific control point. Since there are many control points, the resulting diagram shows a confusing maze of points. These have been simplified by recording the median value for all of the points representing one zone. The median is located by drawing a horizontal line which divides the points into an equal upper and lower half and then a similar vertical line to give equal numbers to left and right. The intersection of these two lines is the median point.

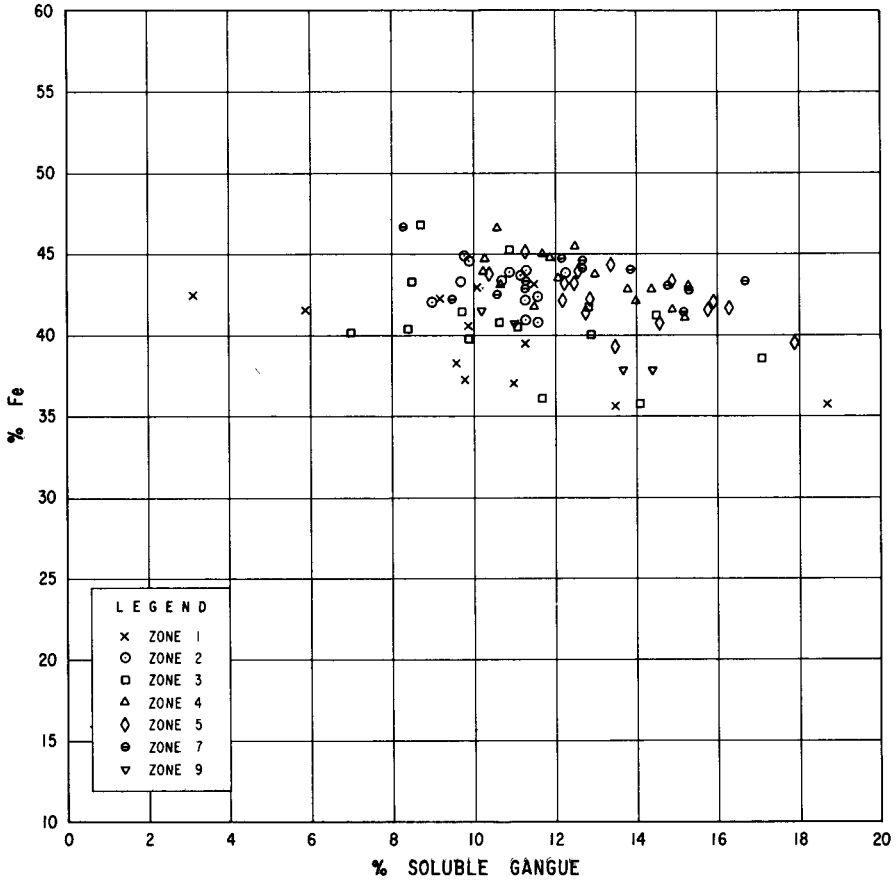
The first chart on page 104 shows that there is no particular relationship between the iron content and the soluble gangue. One can see, however, that zones 1, 3 and 9 have median values of about 40% Fe, while zones 2, 4, 5 and 7 are substantially higher at 43% to 44% Fe. The soluble gangue varies from 10% to 13%. No plot was made of iron versus insoluble gangue. These are the two principal ore components so that there is naturally an inverse relationship between them.

In the chart of soluble gangue versus insoluble gangue on page 105 zones 1, 3 and 9 have a higher insoluble content than do zones 2, 4, 5 and 7 which is simply an illustration of the inverse relation between iron and insoluble assays. The median plot shows that there is a general inverse relation between the soluble and insoluble gangue. Zone 9 is an exception to this rule but it is a zone with poor assay control.

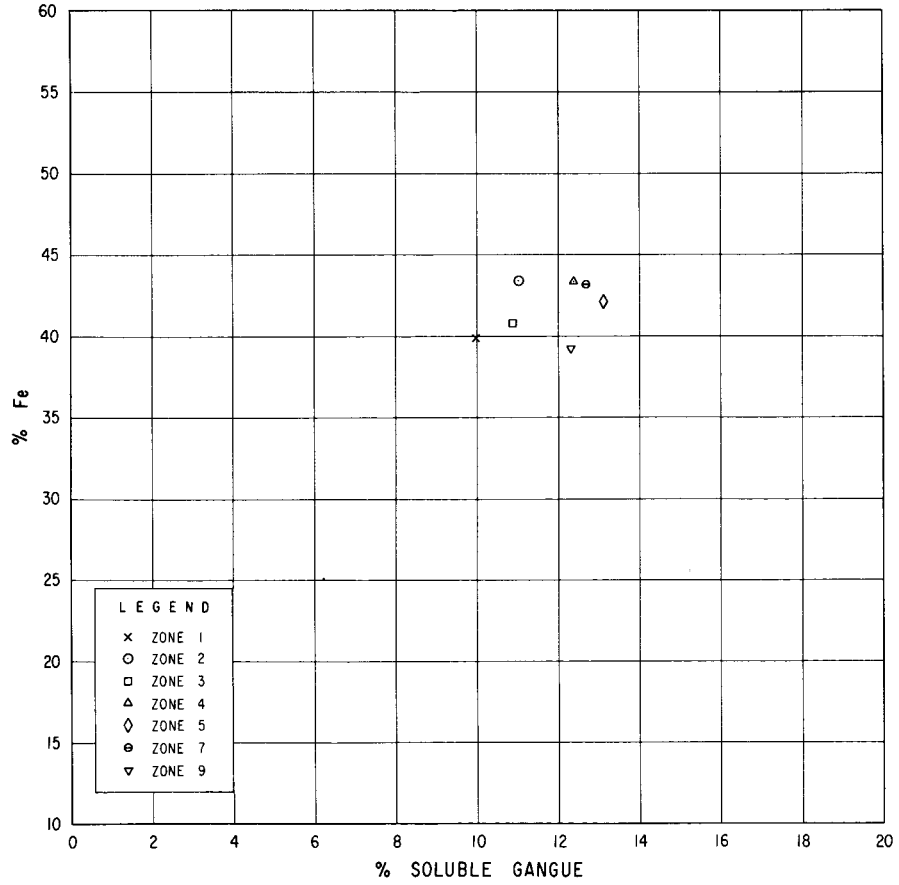
The phosphorus versus insoluble chart on page 106 shows that there is no significant relationship between these two components. Zones 1, 3 and 9 have median insoluble contents of 31% to 34% and zones 2, 4, 5 and 7 of 24% to 27% as in previous charts. The median phosphorus content varies from 0.22% to 0.65%.

However, there is a significant pattern in the median plot of the soluble gangue versus the phosphorus content on page 107. Most of the median points fall fairly close to a straight line which suggests that phosphorus content decreases as the soluble gangue content increases. However, it is also worth noting that the zones are distributed in sequence with 1 at the lower right and proceeding through 2, 3, 4, 5 and 7 to 9 at the upper left. This sequence is imposed on the chart by the previously observed decrease in phosphorus from a high median value to 0.65% in zone 1 to the low median value of 0.22% in zone 9. It is possible that the chart really illustrates two separate vertical changes within the ore zone, rather than a relationship between components. The statement that there is a general increase in the soluble gangue content in successively lower ore zones satisfies the plotted data equally well. The question of whether the phosphorus is related to the soluble gangue will have to be determined by petrological work rather than by statistics.

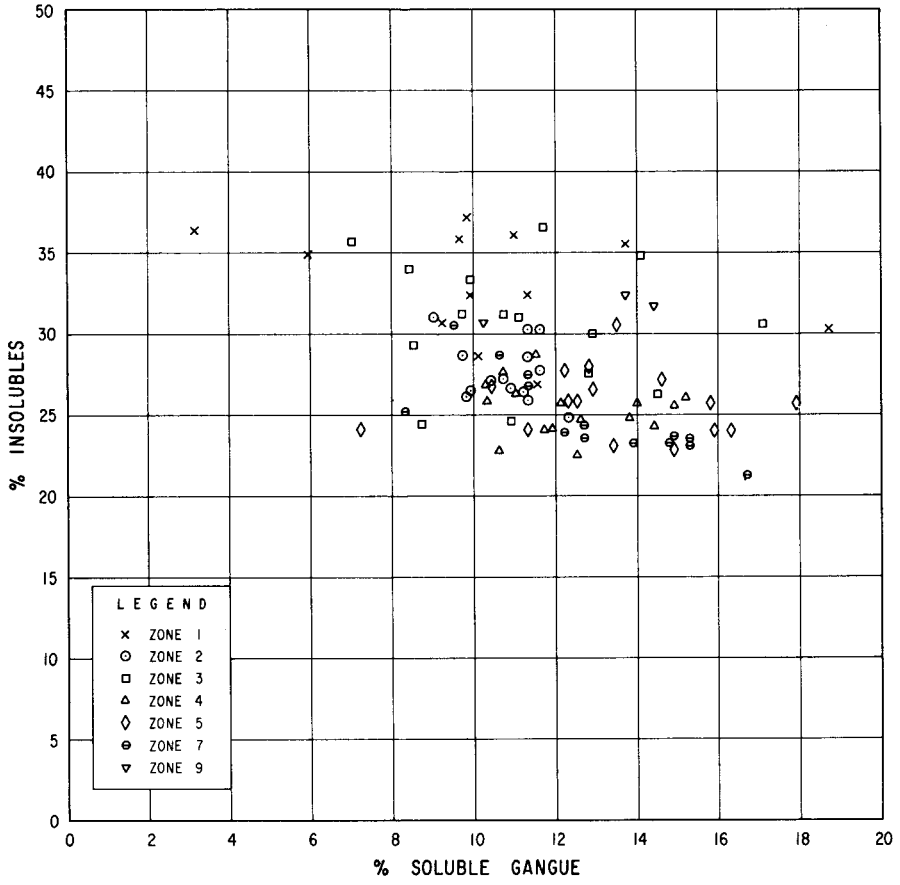
IRON VS SOLUBLE GANGUE - ALL ZONES



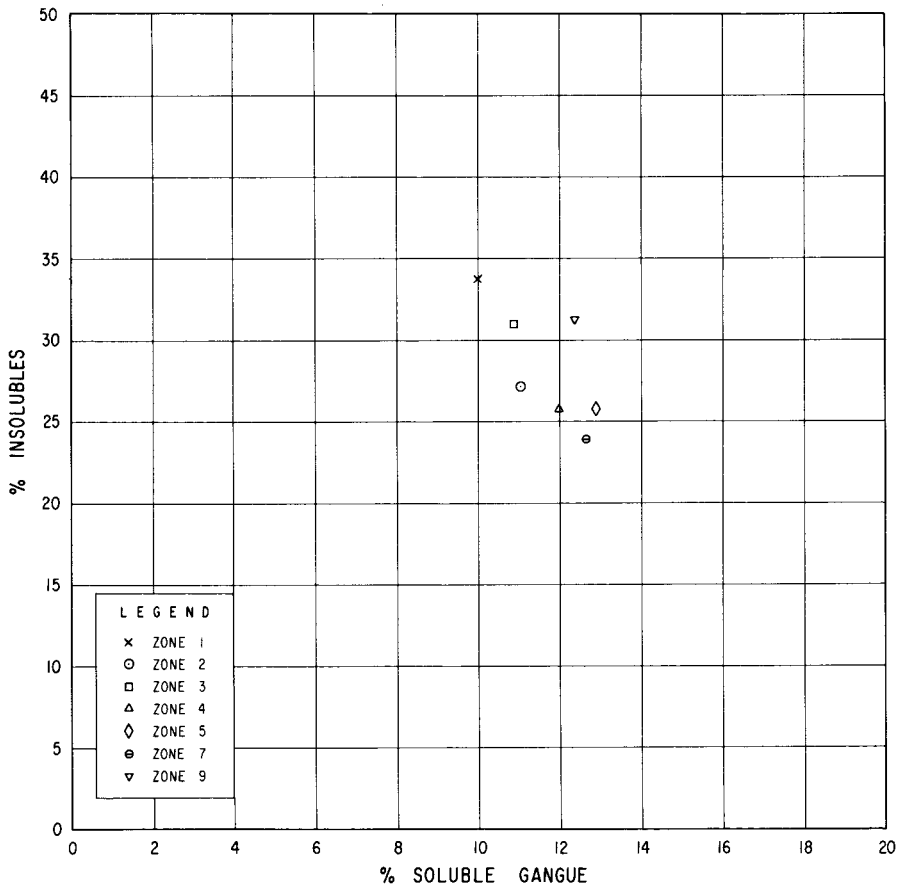
IRON VS SOLUBLE GANGUE - MEDIAN PLOT



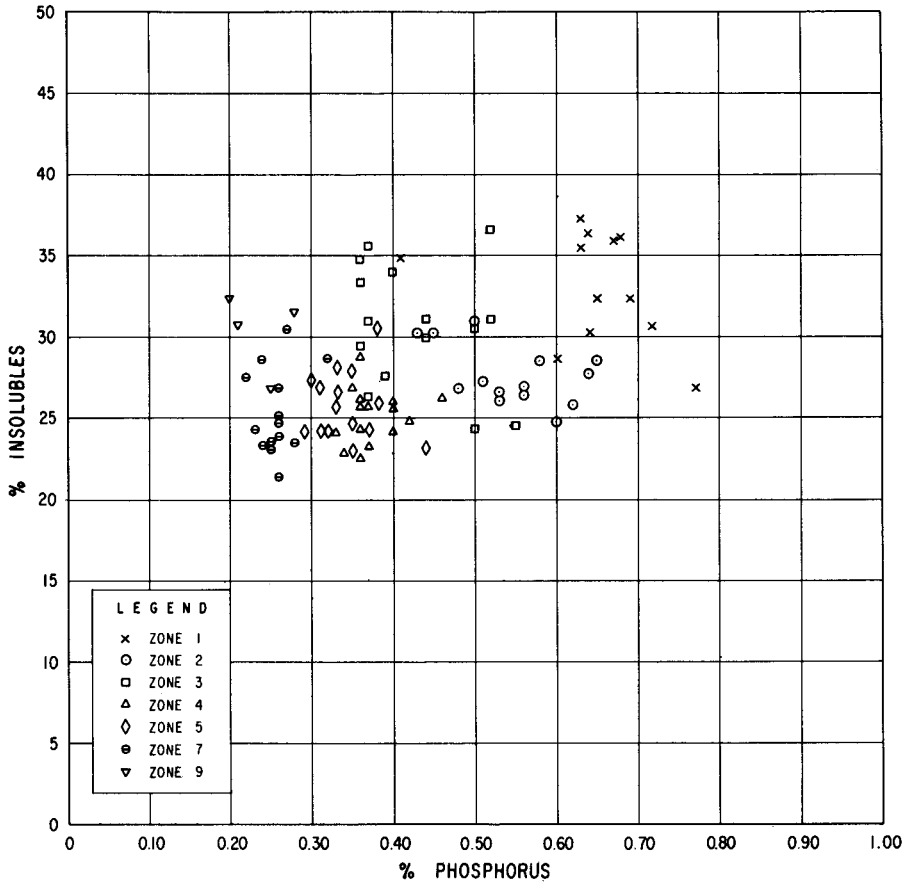
INSOLUBLES VS SOLUBLE GANGUE - ALL ZONES



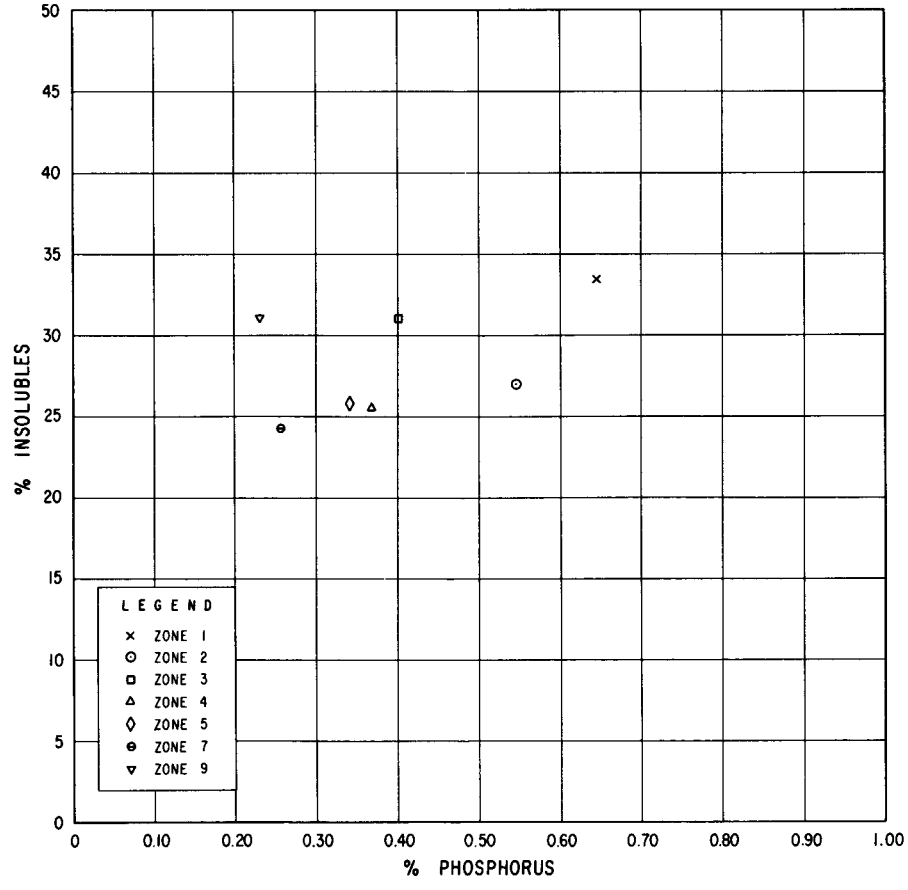
INSOLUBLES VS SOLUBLE GANGUE - MEDIAN PLOT



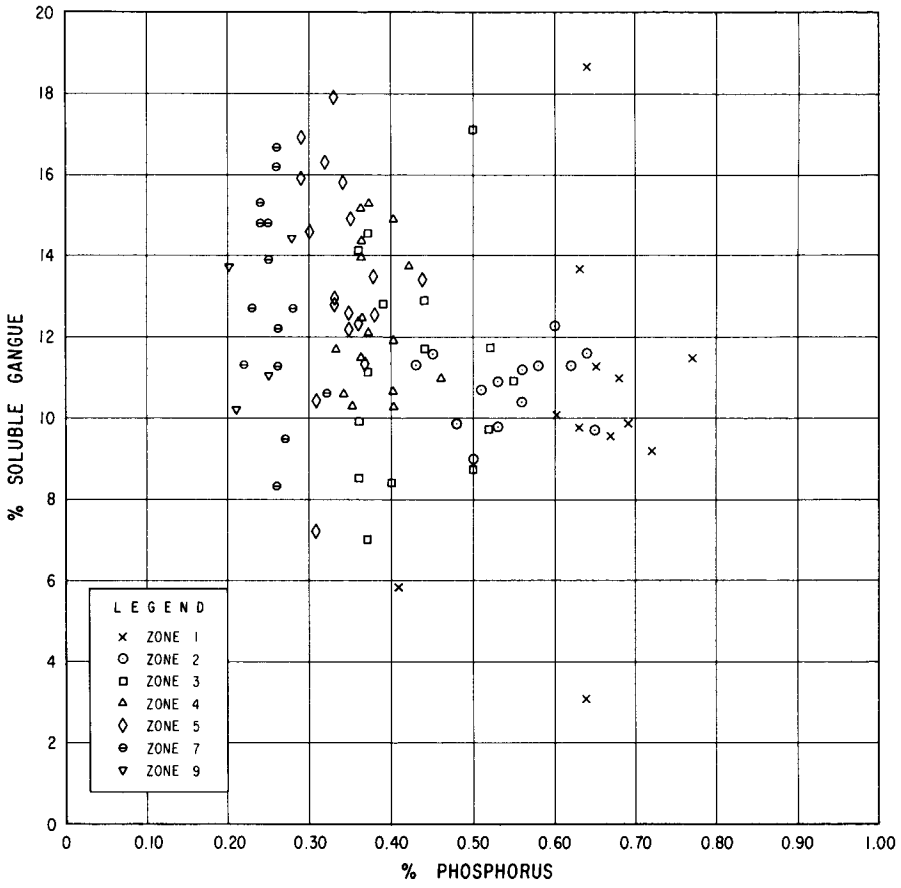
PHOSPHORUS VS INSOLUBLES - ALL ZONES



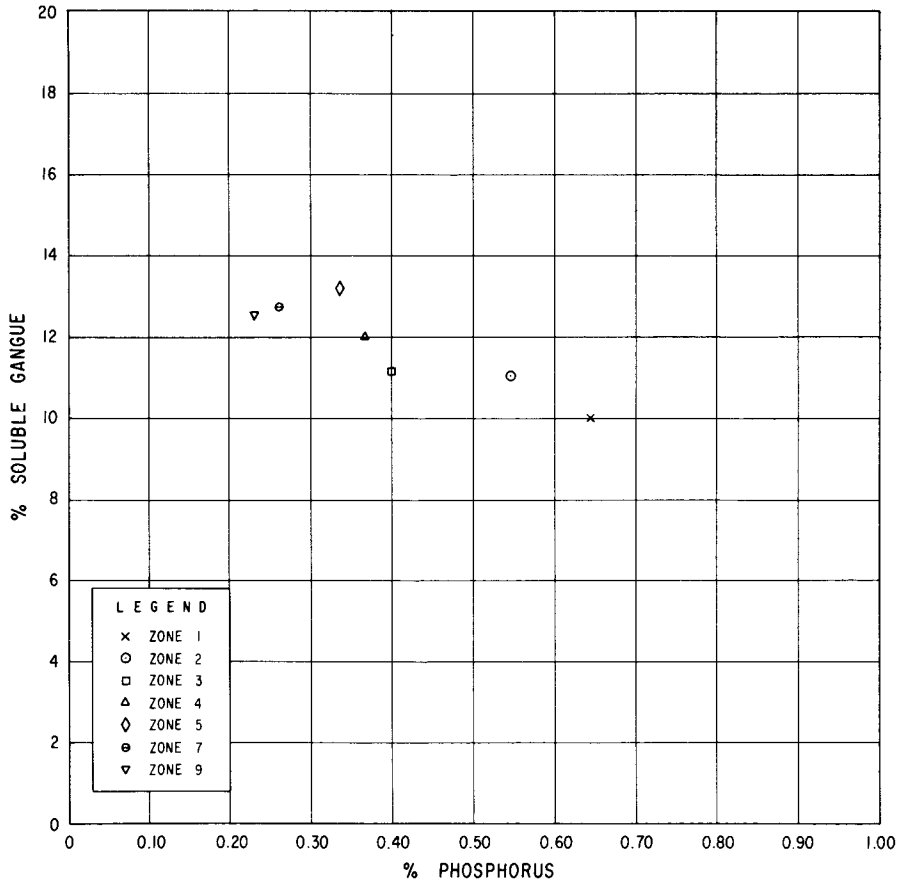
PHOSPHORUS VS INSOLUBLES - MEDIAN PLOT



SOLUBLE GANGUE VS PHOSPHORUS - ALL ZONES



SOLUBLE GANGUE VS PHOSPHORUS - MEDIAN PLOT

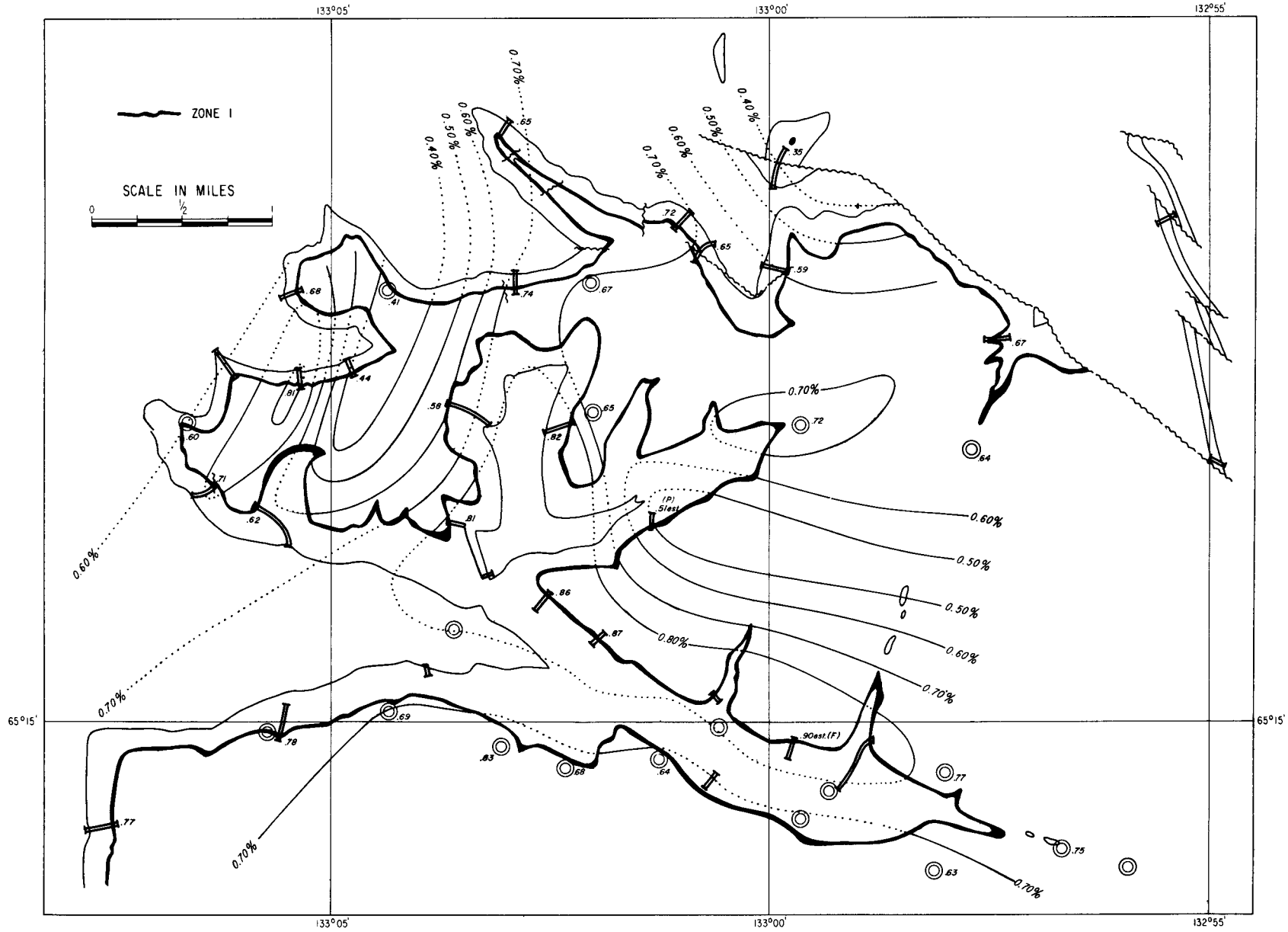


Isophosphorus Maps

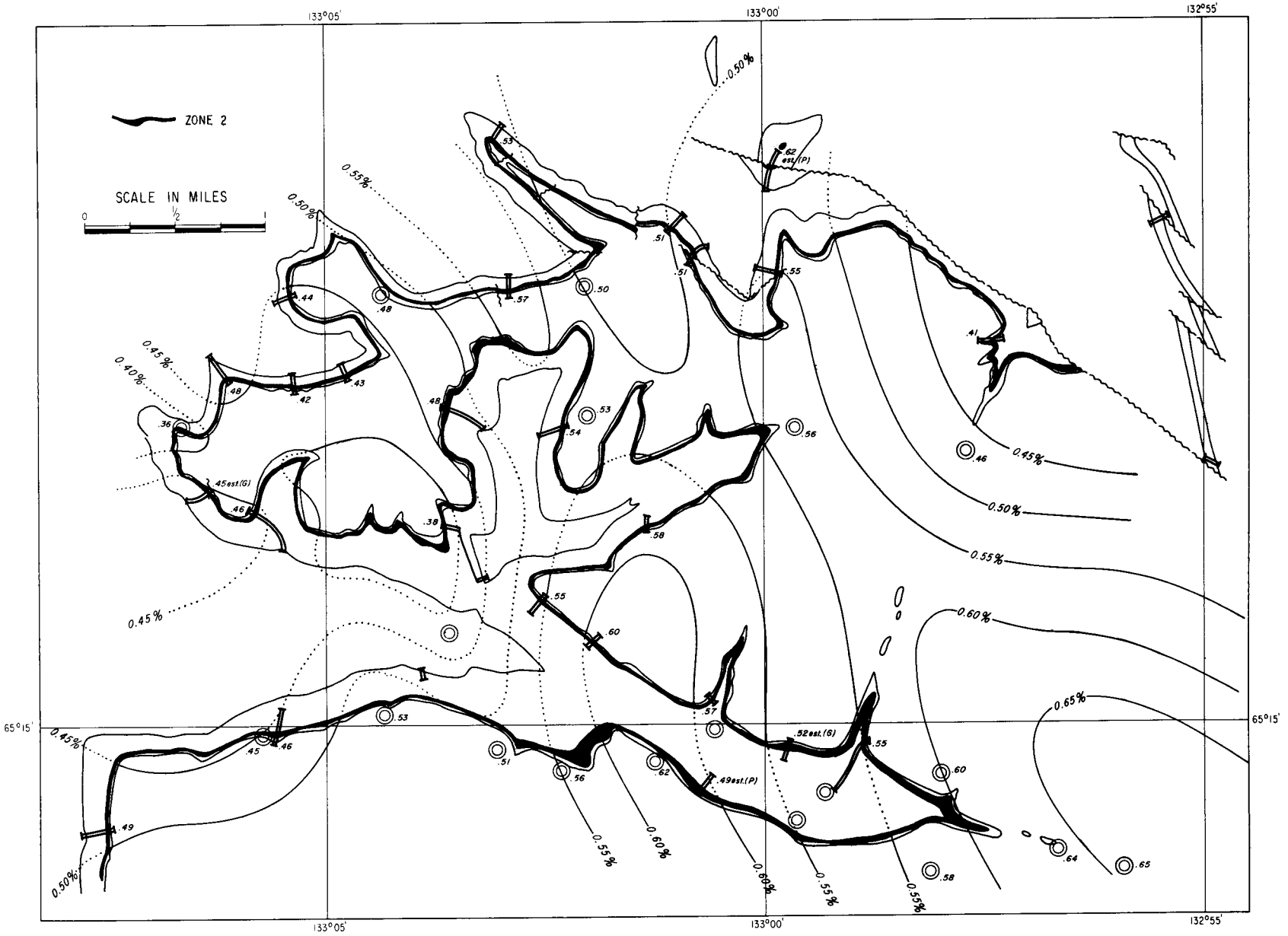
The areal distribution of phosphorus within the ore zones is a matter of considerable economic significance in determining the grade of the mineable ore. The exact nature of its occurrence within a specific horizon is also of importance in beneficiation. Isophosphorus maps were constructed to record the areal distribution and then compared to the isopach maps to see whether the phosphorus was genetically associated with the waste (clastic deposition) or the iron ore (chemical (?) deposition) components of the ore zone.

In general, the overall phosphorus content of the whole main ore zone is highest in Iron Creek where the thickness is greatest. This seems to be confirmed by a rather poor correlation between iron ore isopach thicks and high phosphorus values within individual zones of the iron formation. (See isophosphorus and ore isopach for zone 2). The isophosphorus maps show the same north-northwest and northeast trends as do the waste and ore isopachs, which would suggest that the phosphorus distribution is a function of whichever is dominant of the two depositional processes represented by the iron formation and by the clastic waste. As mentioned in the discussions of the ore and waste isopachs, these trends may be determined by the clastic elements from which one would infer that the phosphorus distribution is controlled by some factor in clastic deposition. This cannot be taken to mean that the phosphorus is a simple clastic component because the clastics consistently have a low phosphorus content. The isophosphorus maps record a pattern of phosphorus distribution but provide no definitive data as to the origin of the pattern.

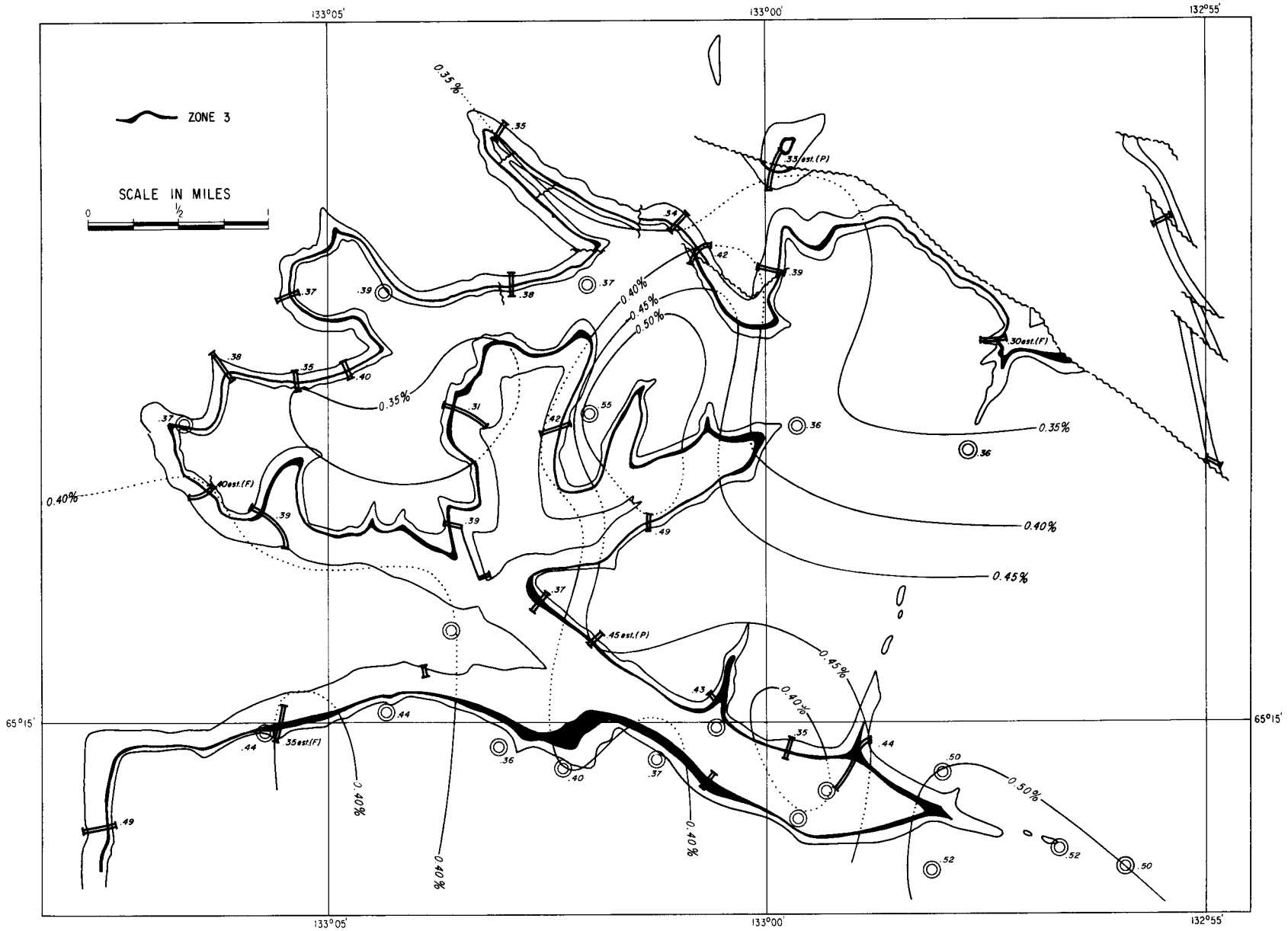
IRON CREEK AREA - PHOSPHORUS CONTENT OF IRON ORE, ZONE I



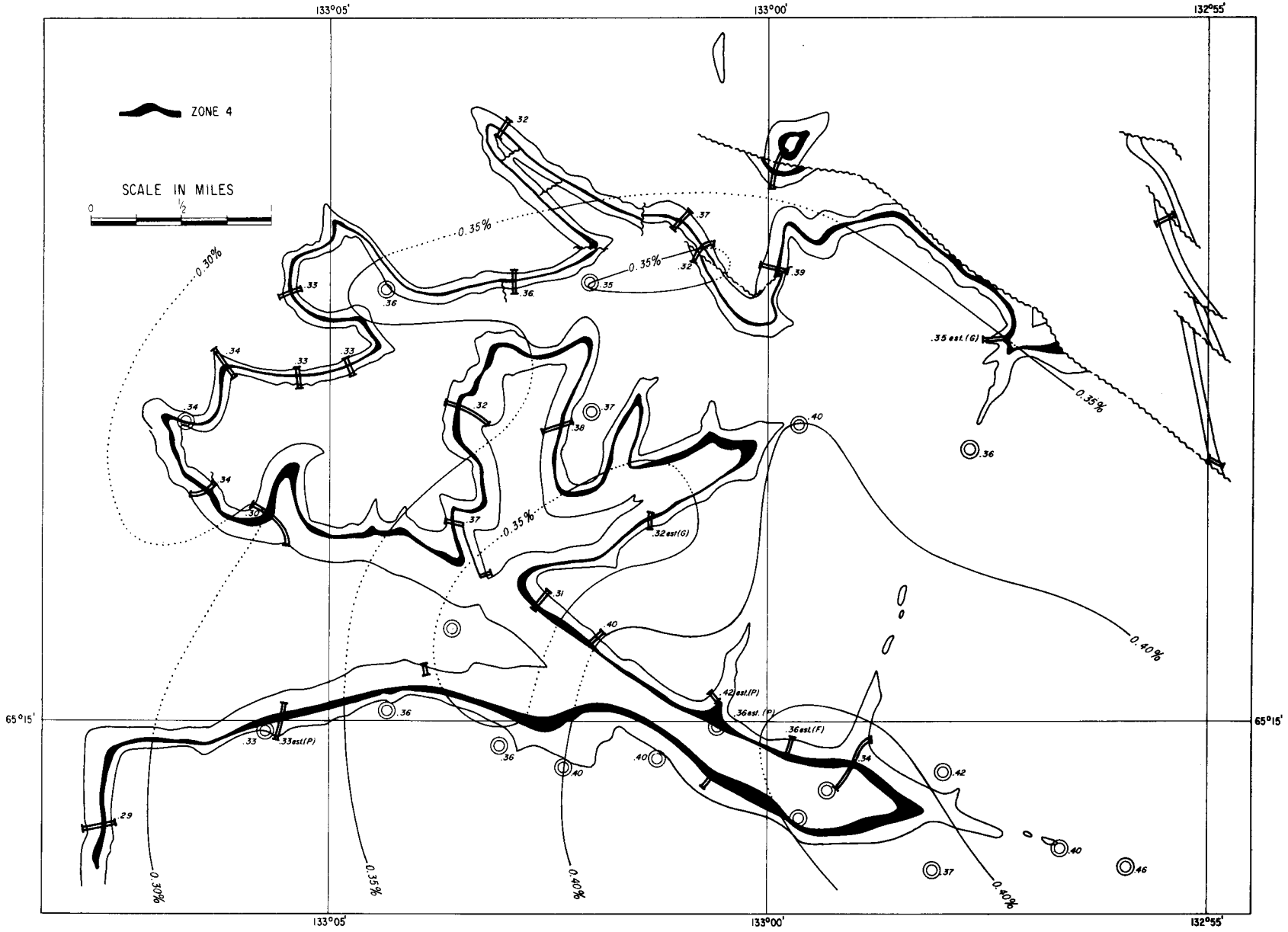
IRON CREEK AREA - PHOSPHORUS CONTENT OF IRON ORE, ZONE 2



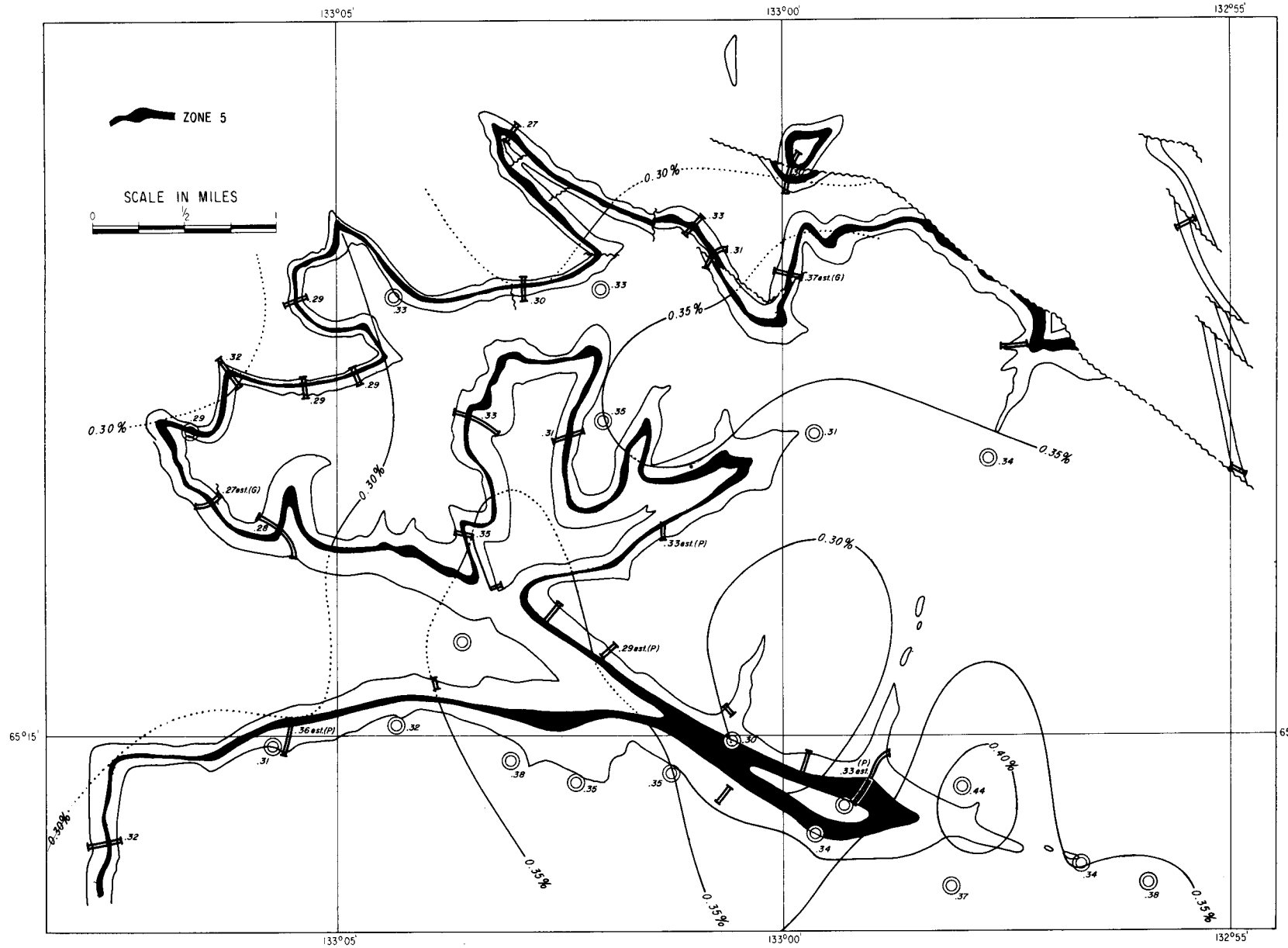
IRON CREEK AREA - PHOSPHORUS CONTENT OF IRON ORE, ZONE 3



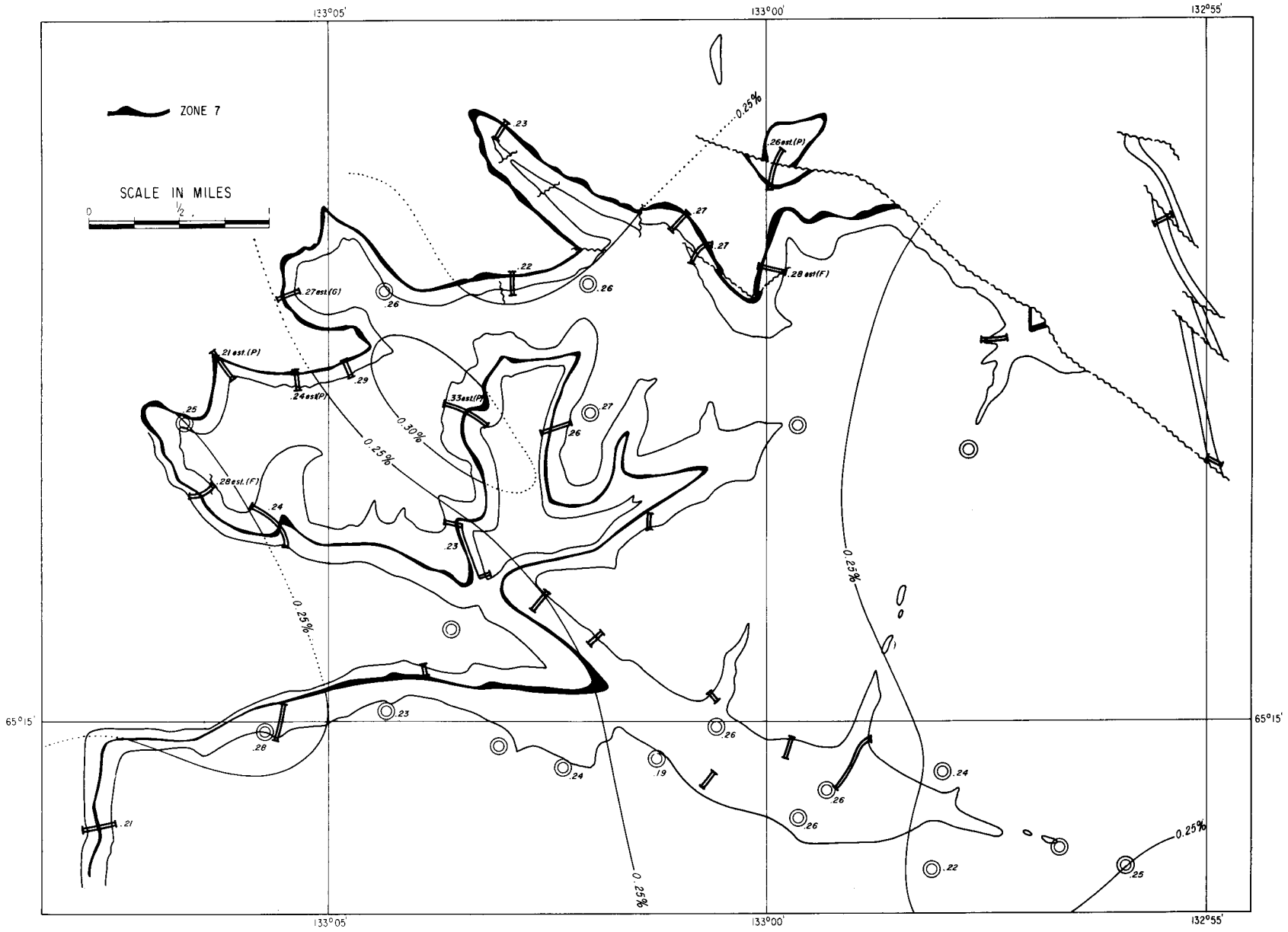
IRON CREEK AREA - PHOSPHORUS CONTENT OF IRON ORE, ZONE 4



IRON CREEK AREA - PHOSPHORUS CONTENT OF IRON ORE, ZONE 5



IRON CREEK AREA - PHOSPHORUS CONTENT OF IRON ORE, ZONE 7



Minor Constituents

The distribution of the minor constituents in diamond drill hole Y-15 is shown on page 116. All of these components are well below the permissible level for premium grade iron ore so that, except for confirmatory assays at other sample locations, very little study has been devoted to the minor constituents. It is worth noting that the higher assays for minor constituents occur in the waste rather than the ore.

The following minor constituents were studied somewhat more than the others.

Sulphur

Quantitative chemical analyses for sulphur were carried out on samples from surface sections 209, 244, 237, 219, 206 and 213. In the ore the percentage of sulphur varied from 0.01 to 0.02%. Several samples from the waste intervals ran as high as 0.08% sulphur. The probable source of the sulphur is the mineral pyrite which is occasionally visible in the drill core. This amount of sulphur is not of consequence since Japanese contracts, on the average, will accept sulphur up to 0.10% without imposing penalties.

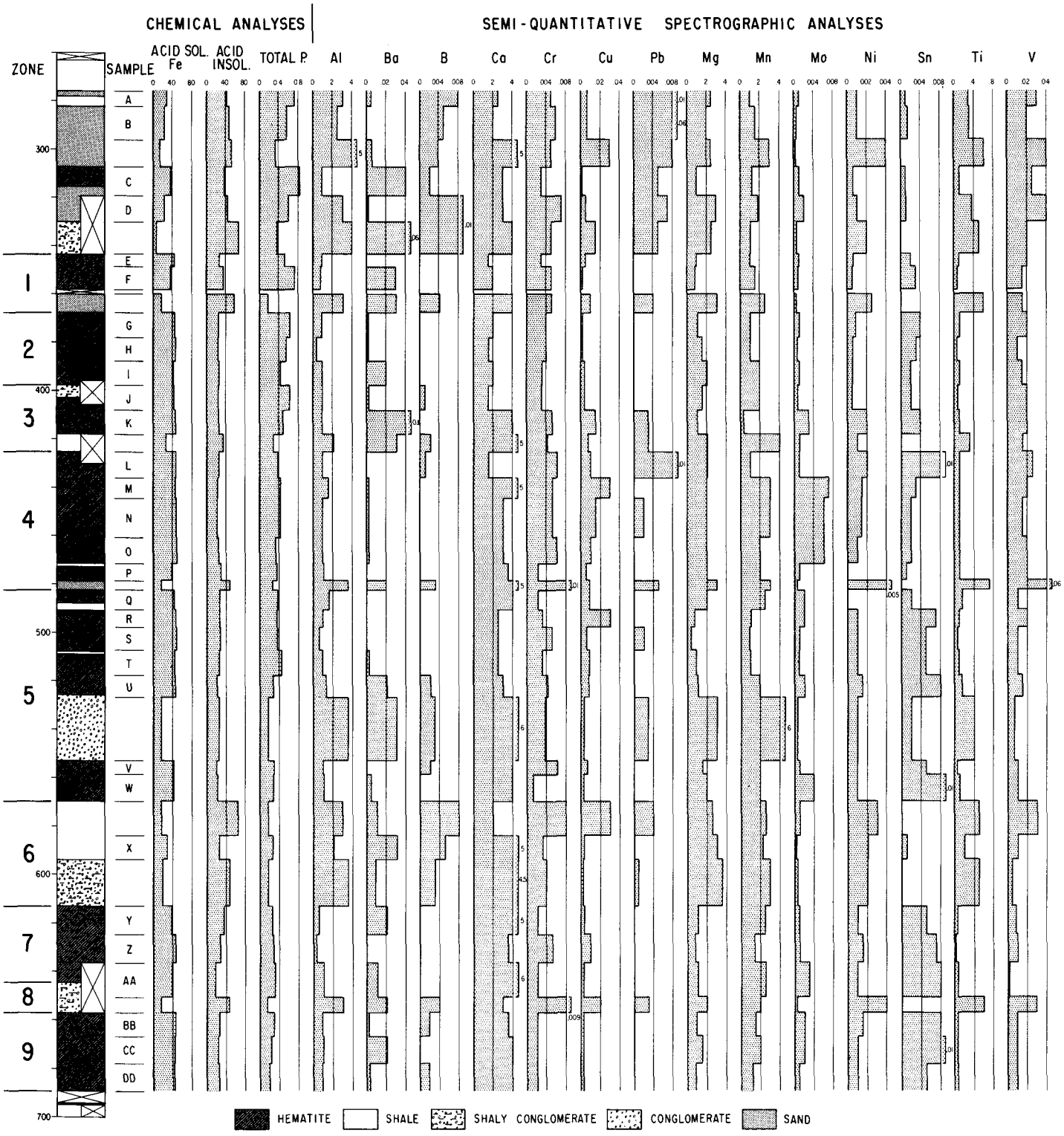
Titanium

Some quantitative spectrographic chemical analyses for titanium were done in 1962 on samples from sections 206 and 213. In 1963 additional titanium analyses were carried out on samples from drill holes Y-7, Y-8, Y-15, Y-17, sections 127, 206 and 312. A marked discrepancy between the 1962 and 1963 titanium analyses for sections 206 and 213 were noticed and verified by check chemical analyses. The 1962 spectrographic plates were re-examined by Coast Eldridge and corrected analyses were forwarded.

The figure on page 117 shows a plot of titanium versus iron. A line representing the ore-waste cut-off is shown at 35% Fe, and a second line showing the Japanese anticipated minimum specification for the maximum amount of allowable titanium is drawn at 0.25% Ti. With the exception of two analyses, all the analyses containing more than 0.25% Ti represent material contained in the waste zones. The iron ore itself contains between 0.02 to 0.11% titanium and the jig concentrates assayed 0.07 to 0.10% which are both well below the maximum allowable titanium content.

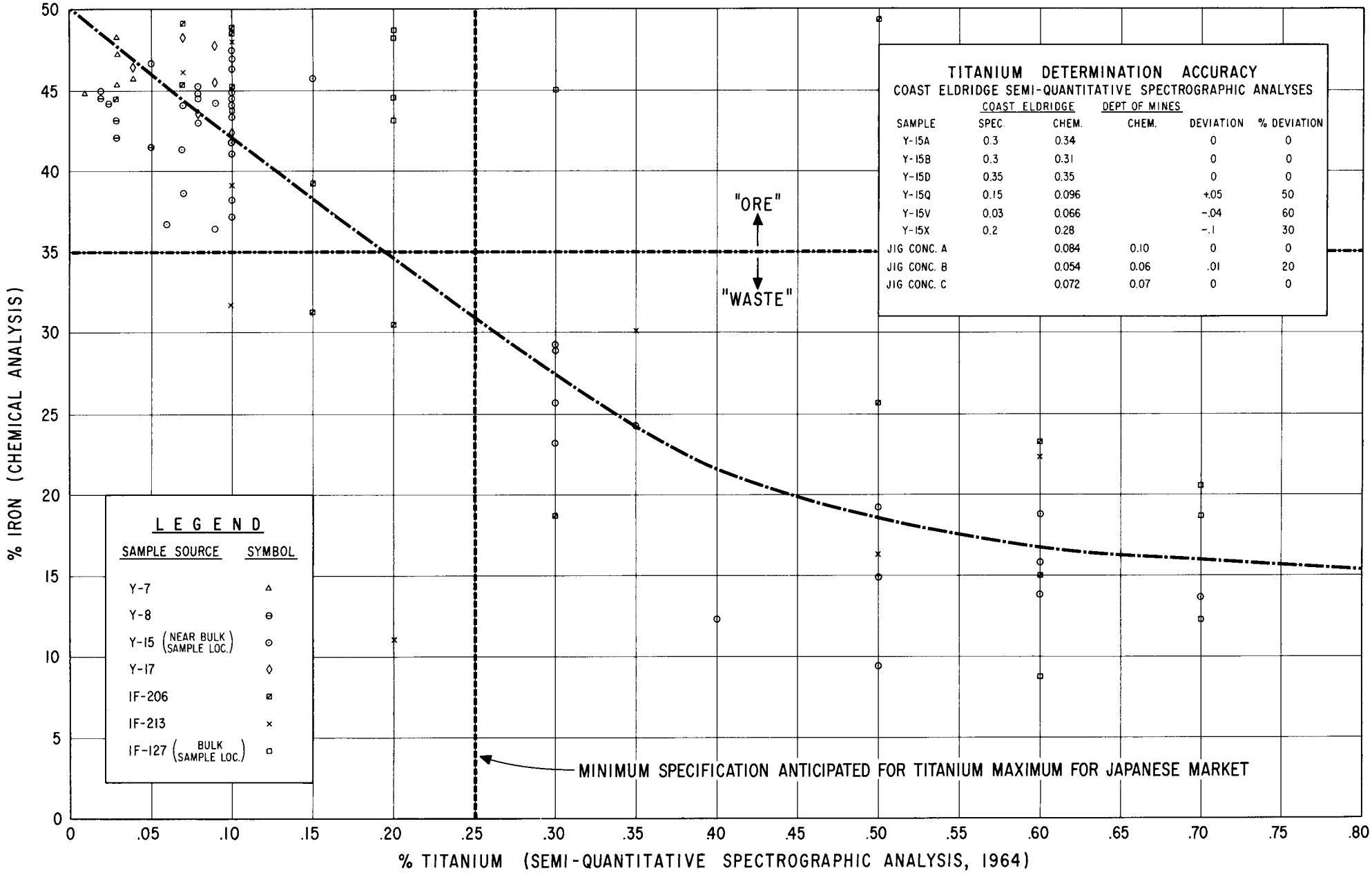
Mineralogical examination has shown a little leucoxene in the clastics but probably other titanium minerals occur in minute amounts.

ANALYSES OF IRON CREEK ORE ZONES
DIAMOND DRILL HOLE Y - 15



NOTE: SPECTROGRAPHIC ANALYSES FOR Sb, As, Be, Bi, Cd, Co, Ga, Au, Nb, Ag, Sr, Ta, W, Zn ARE NOT SHOWN BECAUSE THEY WERE NOT DETECTED OR PRESENT ONLY IN "TRACE" AMOUNTS.

TITANIUM VS IRON
SNAKE RIVER CRUDE MATERIAL



TITANIUM DETERMINATION ACCURACY
COAST ELDRIDGE SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSES

SAMPLE	COAST ELDRIDGE SPEC.	COAST ELDRIDGE CHEM.	DEPT OF MINES CHEM.	DEVIATION	% DEVIATION
Y-15A	0.3	0.34		0	0
Y-15B	0.3	0.31		0	0
Y-15D	0.35	0.35		0	0
Y-15Q	0.15	0.096		+.05	50
Y-15V	0.03	0.066		-.04	60
Y-15X	0.2	0.28		-.1	30
JIG CONC. A		0.084	0.10	0	0
JIG CONC. B		0.054	0.06	.01	20
JIG CONC. C		0.072	0.07	0	0

Manganese

Semi quantitative spectorgraphic analyses for manganese were carried out on samples from surface sections 206, 209, 213, 127 and drill holes Y-7, Y-8 and Y-15. The manganese content ranges from 0.02 to 0.80 with an average of 0.25. The mineralogical form of the manganese is not known.

Alumina

Both quantitative and semi-quantitative spectrographic analyses for alumina were made on several surface sections and diamond drill holes. The alumina content varies from a low of 0.20 to a high of 5.00%. The high values are normally associated with the shale, sandstone and conglomerate horizons. The average alumina content of the iron formation is approximately 0.90%.

Structure of the Snake River Area

The Snake River area is within an east-west trending portion of the Mackenzie Mountains. The regional structure is anticlinal with a steeply north dipping fore limb and a gently south dipping back limb. The fore limb consists of Upper Cambrian to Upper Devonian rocks which dip beneath the Cretaceous cover of the Peel Plateau. The back limb consists of east-west striking south dipping Lower Paleozoic and possibly Precambrian rocks. Both limbs, but particularly the back limb, are cut by steeply south dipping reverse faults.

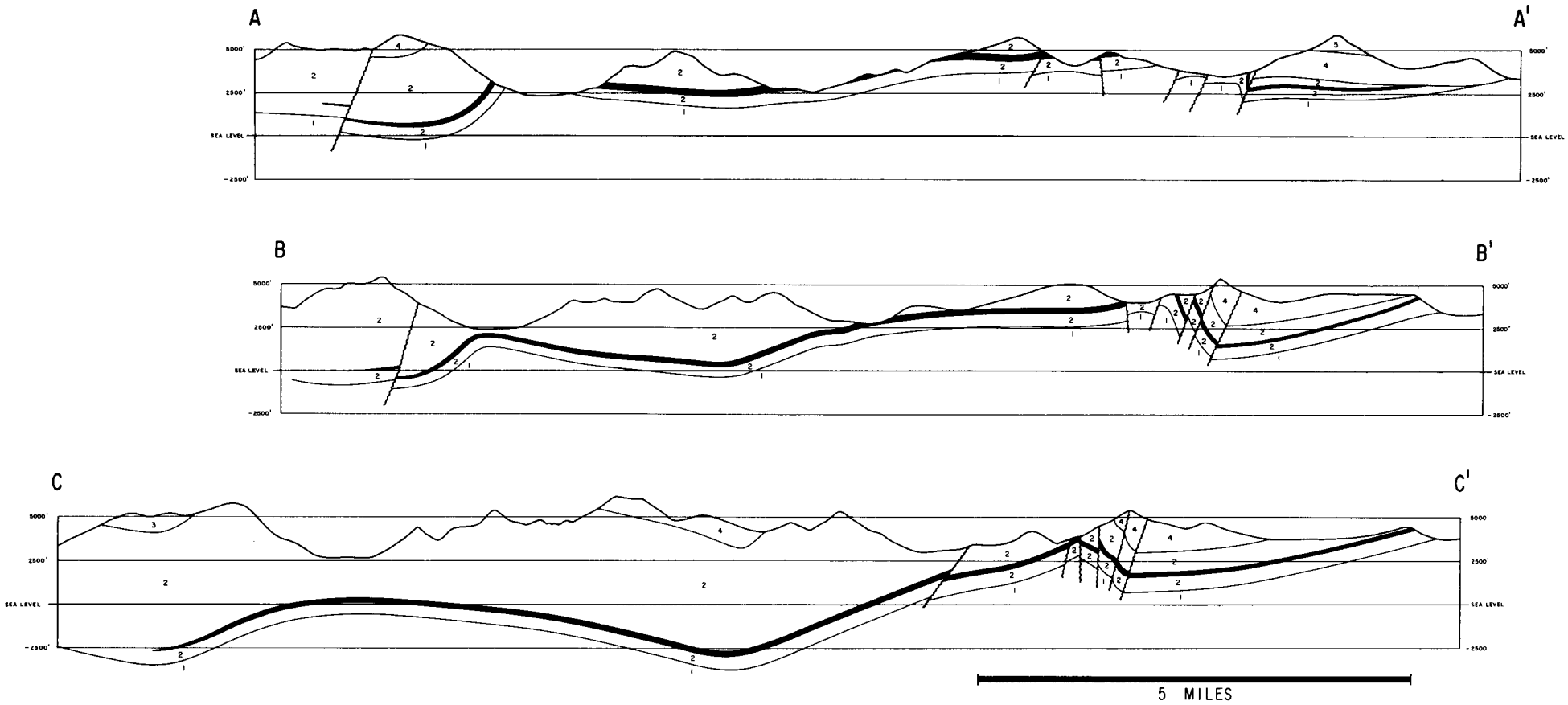
The location of the Snake River area on the back limb of the major Mackenzie Mountain anticline imposes an overall east-west strike and a south dip. However, this gross trend is almost completely obscured by local structures which trend north-west south-east. The reason for the discordance between local and regional trends is not apparent from any data gathered in the mapping at Snake River and presumably an explanation will have to be sought in a study of the overall patterns.

The major structural features of the area are three major northwest-trending westerly-dipping reverse faults that divide the area into three blocks. The westernmost or "Iron Creek" block is from ten to fifteen miles wide and extends west of the map-area to a boundary fault west of the Snake River. This block is folded along northwest-trending axes into several anticlines and synclines. The folds are broad and the strata generally dip at less than twenty degrees except where they steepen near faults, as at the eastern edge of the block where the east limb of the easternmost anticline is vertical to overturned adjacent to the boundary fault. The overall structure of the Iron Creek block is shown in the cross sections which also show the nature of the eastern fault boundary (page 120). Detail structure in the potential pit areas in the Iron Creek block is illustrated by the structure contour map on page 121. The overall plunge of the folding is to the south because of the regional dip.

Within the Iron Creek block there is northeast dipping reverse fault cutting the carbonate map units 4, 5 and 6 south of the headwaters of Iron Creek. (See geological map on page 5). The northern extent of this fault is not known as it disappears into the conglomerate which has no good horizon marker to show displacement. The last exposure of the fault is as a klippe on the high carbonate ridge immediately west of the point where the fault disappears into the conglomerates. To the east along the carbonate-conglomerate contact there is a point where the boundary fault between the Iron Creek and Discovery Creek block changes character. North of this point the boundary fault is a steeply dipping zone marking the crest and west facing fore limb of an anticline. South of this point the boundary fault is clearly a thrust with a much flatter southwest dip.

This data is open to two interpretations. On the geological map the two inwardly dipping thrusts have been joined by an inferred fault along the contact between the Cambro-Ordovician carbonates and the underlying carbonates. This implies that the carbonates between the two northwest trending thrusts are a shallow thrust plate which have been thrust northward on a southeast plunging folded (?) sole fault overriding the steep dipping faults below. Alternatively, the inferred bedding plane fault at the conglomerate - carbonate contact may not exist at all and the two faults may be separate thrust faults which are both steep dipping in the north and gentler dipping in the south.

SNAKE RIVER AREA STRUCTURAL CROSS SECTIONS



LEGEND

SILURO-ORDOVICIAN

5 BLOCKY CARBONATE

CAMBRO-ORDOVICIAN

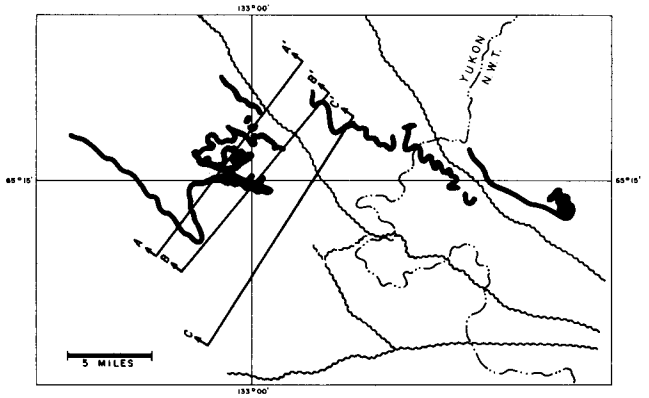
4 CARBONATE (Upper shaly, lower blocky with major unconformity at base.)

CAMBRIAN?

3 SHALE

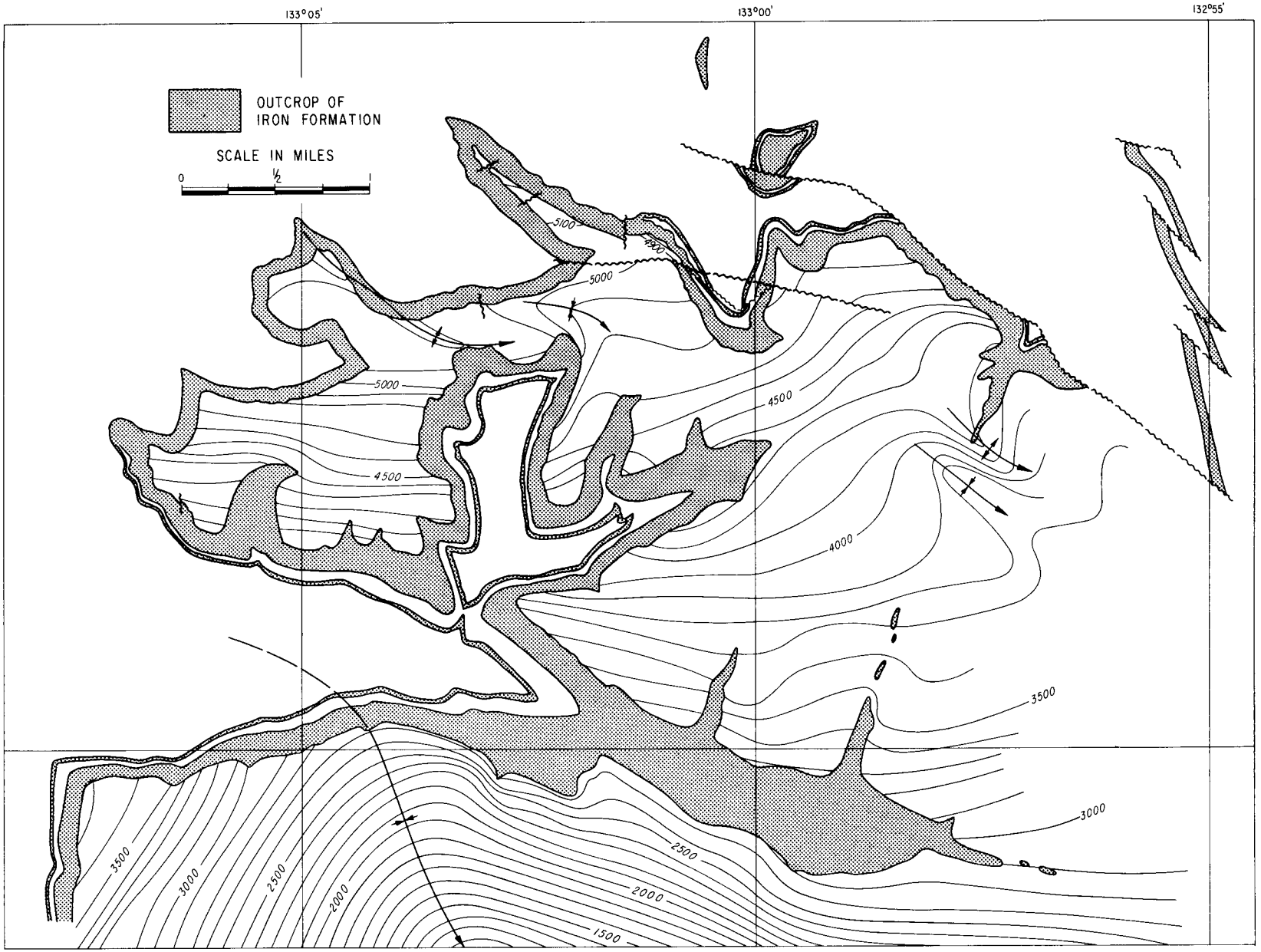
2 SHALY CONGLOMERATE WITH IRON FORMATION

1 UNDIFFERENTIATED



LOCATION MAP

IRON CREEK AREA - STRUCTURE CONTOURS ON TOP OF MAIN ORE ZONE



The overall plunge is south so the gently dipping section would then represent a higher structural level than the steep dipping section. This interpretation would make the rectangular conglomerate outcrop pattern at the head of Iron Creek a consequence of a south plunging box anticline with steep thrusts rising out of each limb and flattening out upward. This kind of structure is more in keeping with what is known of the regional pattern than the alternative of a major flat thrust. Exposures are adequate to settle this question decisively when the opportunity to do adequate mapping arises.

The central or "Discovery Creek" fault block ranges in width from seven miles at the north to five miles at the south. It consists of a block of relatively underformed, predominantly west-dipping strata with gentle plunges to the northwest and southeast from a culmination at latitude 65° 15' N. to 65° 20' N. Locally the strata are crumpled against the western boundary fault, and dragged into steep northeast dips against the eastern boundary fualt, but otherwise they dip southwesterly at less than fifteen degrees. The western boundary fault, which raises the Iron Creek block 2000 to 3000 feet relative to the Discovery Creek block, changes character from a simple fault in the northwest and southeast to a complex zone of faulting and tight folding in the centre. The tight folding is restricted to a very narrow zone adjacent to the fault, and occurs in the same area in which vertical to overturned beds may be observed in the Iron Creek block on the hanging wall of the fault. An anticlinal drag fold is located at the eastern boundary fault of the block in the vicinity of latitude 65° 15' N. This fold, the axis of which is slightly oblique to the trend of the fault, strikes into the fault to the south and passes into southwest-dipping monoclinal beds to the north. The eastern boundary fault is a single well-defined break that dips steeply to the southwest and displaces the hanging wall at least 2500 feet upward with respect to the footwall.

The eastern or "Cranswick River" fault block resembles the central block both in dimensions and in structure. It is five to seven miles in width, wider in the north than the south, and constitutes a southwest-dipping monocline locally deformed adjacent to the boundary faults. Hematitic conglomerates containing iron formation occur only in the southwestern part of the block and consequently the northern and eastern parts have not been completely mapped and the eastern boundary fault has not been traced along its full length. Within the area the eastern fault exhibits a minimum displacement of approximately 1000 feet, but beyond the area to the southeast the same fault has been observed to displace the hanging wall beds on the west upward at least 2500 feet relative to the footwall beds on the east. The magnitude of this fault is, therefore, similar to that of the other major faults in the area. The sedimentary strata constituting the Cranswick River fault block tend to dip slightly more steeply than those in the two blocks to the west and dips between twenty and thirty degrees are common in the southwest part of the block.

The southwest margin of the map area is marked by a major east-west trending steep dipping thrust fault. The stratigraphic displacement on the fault is in excess of 7000 feet. The relationship of the boundary faults to this east-west trending thrust have not been studied in detail. In the overall pattern the boundary faults seem to swing into and join the east-west thrust fault rather than being cut and overridden by it. Several smaller thrust faults with the same east-west trend occur within the major fault blocks and are presumed to join (?) with the boundary faults. The two major fault trends may have developed more or less simultaneously and may not represent separate structural episodes.

Conclusions

The sedimentary structures and consistent stratigraphy of the Snake River iron deposit leave no doubt as to its relatively simple sedimentary origin. Although there is abundant evidence of local replacement, it is very probable that this replacement is a diagenetic feature representing a redistribution of constituents already in the sediment or its contained connate water rather than an addition of iron from an external source. There has been no post depositional enrichment of the iron formation by leaching which characterizes so many other iron deposits. The Snake River iron ore at 40% to 45% Fe is a high grade representative of the "protore" of other iron ranges which is usually in the range of 30% to 35% Fe.

The relatively unaltered state of the iron formation and the good exposures make the Snake River area an ideal locality to study the origin of iron deposits. However, the work discussed in this report has been directed toward the collection of data which is directly applicable to the economic evaluation of the property and scant attention has been given to the academic problem of iron ore genesis. Those who favour vulcanism as the ultimate source of the iron will be interested in the tuffaceous nature of some of the Snake River clastics. Those who favour a more prosaic sedimentary process for the production of iron ore will be interested in the incermittent distribution of Rapitan iron formation over a 500 mile arc on the north and east slopes of the Mackenzie Mountain system from the Tatonduk River on the Alaska border to Dall Lake in the headwaters of the Redstone River in the Northwest Territories. The work at Snake River has not provided any decisive evidence on the ultimate source of the iron.

Evidence has been obtained in the sedimentary processes involved in the deposition of the iron formation. The shaly conglomerate component could conceivably have been deposited as a tillite in association with glaciation, by turbity currents or by mud flows. The evidence cited in the foregoing sections is almost conclusively in favour of a thixotropic mud flow mechanism. The sandstones such as the marker sands are quite normal clastic sediments but perhaps their association with the shaly conglomerates would suggest a turbidite origin. The bedded character of the jasper-hematite rocks and the evidence of its rather gelatinous nature after deposition suggests that they may have been deposited as some form of precipitate.

Recommendation

No further geological field work is necessary until a decision to resume active exploration has been justified by improved economics. In the interim there is much detailed work on core hole and surface section data and on the petrology of the ore which has not been done and which may be needed.

The petrology is most apt to be of immediate interest because of its application to the beneficiation studies. To this point only enough petrology has been done to establish the mineralogical constituents in the ore and the textures which characterize the macroscopically recognizable rock types. This work has been restricted to selected samples, particularly from the upper part of the section. No attempt has yet been made to do a detail analysis of textural characteristics throughout all of the ore zones, although it is recognized that this information will be required for a thorough understanding of the ore's response to beneficiation. However, the beneficiation testing is still at the stage where the nature of the response to various concentration techniques is being established empirically. The detailed investigations required to understand and thereby improve the results of beneficiation might best be deferred until a specific process of particular promise has been selected.

Either in connection with the petrological work mentioned above or separately, further work should certainly be done to determine the nature and distribution of the phosphorus bearing minerals within the hematite. Such a study requires equipment which can be used to locate and to identify minute gangue particles in the 10 micron size range in polished section. The usual metallographic microscopes were found to be hopelessly inadequate so that access to more sophisticated equipment must be obtained.

Economic Study by Crest Exploration
Lat. 65°10' N to 65°20' N; Long.
132°45' W to 133°15' W
D.W. Miller, Financial & Economic
Analyst
June 1963 - Oct. 1964

CANADA

Department of Northern Affairs and National Resources — Resource Development Branch — ~~Northern Administration Branch~~

Ministère du Nord canadien et des Ressources nationales — Direction du Développement des Ressources — ~~Direction des régions septentrionales~~

Box 2703,
Whitehorse, Yukon,
November 5, 1965.

MINING RECORDER, MAYO, YUKON

our file / notre dossier M.I. M-252

your file / votre dossier

Reports on
Crest Exploration Limited
Snake River

On the recommendation of the Resident Mining Inspector I hereby authorize you to accept the following mentioned reports submitted by Crest Exploration Limited. Valuations of these reports are given to the right opposite the title:

	Value for Representation Work
1. Yukon Iron Ore Railway Feasibility - J. L. Charles	$15,000.00
2. (a) Report of Froth Flotation and other Beneficiation Tests - A. R. Rice et al	
(b) Report on Column Flotation Testing of Snake River Ore - Pierre Boutin	$38,000.00
(c) Metallurgical Evaluation Report - James E. Lawver	
3. Economic Study by Crest Exploration - D. M. Miller	$ 2,125.00

A copy of the recommendation and a copy of the authorization should be placed on the claim file concerned.

Would you please see that copies of these reports and copies of the recommendation and authorization are sent to the Geological Evaluation Unit in Ottawa and that copies are sent to the Central Records Office - Mining in Whitehorse.

The report on Water Gauging Project at Snake River is not acceptable as representation work.

G. R. Cameron,
Commissioner.

Attach.

cc: Chief, Resource Management Division
Attention: Geological Evaluation Unit
Central Records Mining - Whitehorse

20 Apr. 1972

Preliminary Evaluation:

Yukon - N.W.T. Iron Ore

Crest Exploration Limited

In Commissioner's office

M. Wise

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ORE MARKETING IN GENERAL

Captive and Open-Market Sales

There are two types of iron ore sales, captive sales and open-market sales. Captive sales are the transfer or sale of iron ore to an iron or steel plant owned by the same company that owns, or shares in the ownership, of the mine from which the ore is shipped. Open-market sales are normally made through long term contracts covering periods ranging from a few years to as many as twenty-five. Spot sales which fall within the open market classification, cover transactions extending over a period of not more than one year, are much less important than sales through long term contracts and are almost non-existent in periods of slack demand for iron ore.

In the three major marketing areas of the world, United States, Japan and Western Europe, we find variation in the pattern of captive and free market sales.

The iron ore market in the United States is mainly a "captive" market, with large integrated steel producers owning the iron mines. It has been reported that the major steel producers consider it advisable to own or control iron mines and beneficiating plants both in the United States and abroad, capable of producing from 70% to 80% of the ore requirements of individual companies. Thus, in periods of peak steel demand, the major steel producers are assured of the bulk of their requirements of iron ore and rely on independent producers for only a small part of their total needs. In periods of slack demand, on the other hand, the major iron and steel producers reduce their open-market purchases of ore insofar as their commitments will allow and thus increase the proportions of their own supply. Under these circumstances mining companies depending heavily on open-market sales of ore for their income suffer a greater decline in production during periods of slack demand than does the industry as a whole.

In contrast to the United States, Japan depends almost entirely on open-market transactions to secure her iron ore requirements. In 1962, Japan purchased ore from 13 different countries and over 60 separate mines. In order to assure a sufficient supply of ore and to promote export, Japanese assistance has often been granted to foreign sources of supply. Assistance has normally taken the form of credit grants for purchase of Japanese equipment and the advanced funds are repaid out of ore deliveries. This type of arrangement has the effect of locking the Japanese into certain contracts but the term of the credit extension is usually five years or less.

The situation in Western Europe is varied between that of the United States and Japan, with both captive and open-market iron ore supplying requirements. In recent projects, the extension of captive ore operations to foreign countries is in evidence with a group of German companies guarantying loans on the strength of long term contracts in LAMCO of Liberia and British, French, Italian and West German companies investing in the equity of MIFERMA of Mauritania.

Volume and Location of World Market

The United States, the European Coal and Steel Community and Britain, and Japan are, and will continue to be, the major importers of iron ore in the Western World. The following table which shows the world supply and demand

for iron ore in terms of iron content for a year ranging between 1972-1975 is slightly out of date, but the general picture has not changed. Although more up-to-date information would revise the magnitude of the numbers and predict the emergence of Australia as a future exporter, the general conclusions are still valid.

Estimated Iron Ore Requirements by Regions & Selected Countries in 1972-75(1)
(Million Tons)

Region or Country	Pig Iron Requirements	Domestic Ore Production Fe Content(a)	Deficit or Surplus in Iron Ores Fe Content
Eastern Europe	119.6	119.6	-
ECSC & Britain	94.4	47.8	46.6
Other Western Europe	14.7	33.0	(18.3)
United States	78.2	55.0	23.2
Other North America	6.6	35.0	(28.4)
Latin America	12.2	42.0	(29.8)
Africa	4.1	17.3	(13.2)
Japan	24.9	1.2	23.7
Other Far East	22.0	25.8	(3.8)
Middle East	1.2	1.2	-
Oceania	6.4	6.4	-
World (b)	384.3	384.3	-

(a) Losses of iron in enrichment processes have been disregarded.
(b) Excluding Communist China and North Korea.

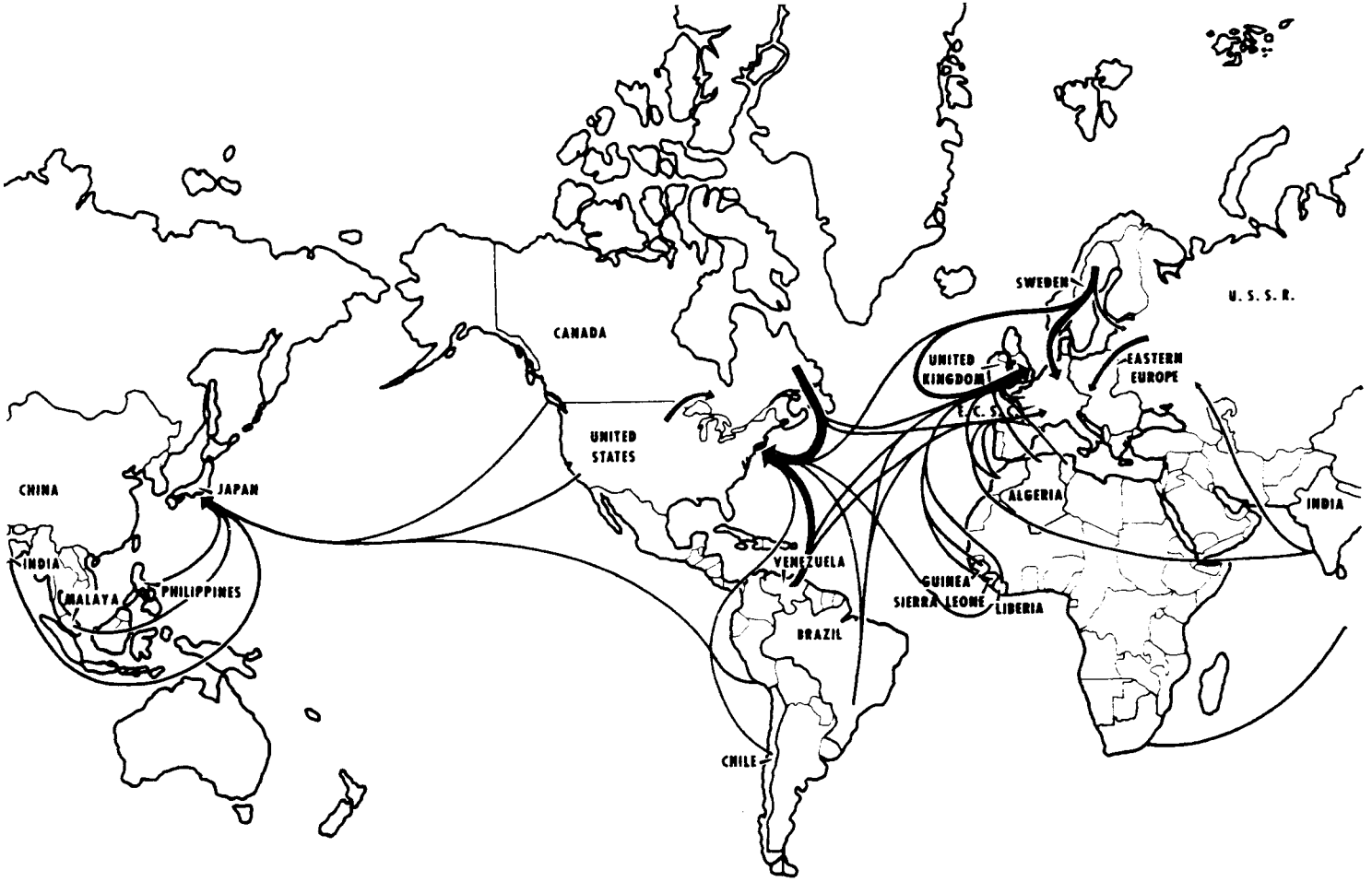
(1) "Long-Term Trends and Problems of the European Steel Industry" United Nations 1959.

World Reserves of Iron Ore

The table of World Iron Ore Reserves and Resources on page H-4 was published in December, 1962. This is not a tabulation of world iron ore resources because it includes only reserves that can be economically exploited in the foreseeable future. The figures represent the iron ore reserves from which the worlds steel industry would be supplied during the next thirty years if there were no demand limitations. Comparable tabulations showing total world reserves are substantially higher than those reported in this table. For example, in January, 1959, reserves equivalent to 132 billion metric tons of iron content were estimated in another source (2) instead of the 71.2 billion tons shown in this table.

(2) The World's Iron Ore Supplies, Dr. F. G. Percival, British Iron and Steel Federation. Revised January, 1959.

INTERNATIONAL TRADE IN IRON ORE – 1962



IRON ORE IMPORTS

MILLION METRIC TONS

	JAPAN	U.S.A.	E.C.S.C. & U.K.
1950	1.4	8.3	14.0
1962	22.2	34.0	45.6
1972-75 Est.	49.0	40.0	75.0

1962

World Iron Ore Reserves and Resources(1)

	Iron Ore			Iron-In-Ore				
	Geologically Explored Reserves			Geologically Explored Res.				
	Direct Shipping Ore	Concentrating Ore	Potential resources	Direct Shipping Ore	Concentrating Ore	Total Explored	Potential Resources	Total
	(Millions of Metric Tons)							
North America								
Canada	573	4,095	7,591	195.2	1,558.4	1,753.6	2,812.8	4,566.4
U.S.	671	7,124	19,983	269.9	2,284.3	2,554.2	6,042.2	8,596.4
Total	1,244	11,219	27,574	465.1	3,842.7	4,307.8	8,855.0	13,162.8
Central America								
Honduras			8				4.2	4.2
Mexico	105		146	60.0		60.0	89.7	149.7
Total	105		154	60.0		60.0	93.9	153.9
South America								
Argentina		106	80		47.5	47.5	36.5	84.0
Brazil	2,815	100	14,050	1,737.0	60.0	1,797.0	8,487.5	10,284.5
Chile	189		259	119.9		119.9	167.1	287.0
Columbia	50		50	24.0		24.0	24.0	48.0
Peru	42	500	52	25.7	275.0	300.7	31.4	332.1
Venezuela	1,039		565	622.7		622.7	316.5	939.2
Total	4,135	706	15,056	2,529.3	382.5	2,911.8	9,063.0	11,974.8
Europe								
Austria	110		230		37.2	37.2	78.1	115.3
Bulgaria	20	250		12.6	81.7	94.3		94.3
Czechoslovakia		70	160		24.3	24.3	54.3	78.6
Finland		250	220		87.5	87.5	64.0	151.5
France	6,020	540	5,120	1,924.0	257.8	2,181.8	1,880.0	4,061.8
Germany - East		35			11.5	11.5		11.5
Germany - West	65	1,457	3,830	19.8	425.9	445.7	1,021.6	1,467.3
Greece		82	85		38.6	38.6	41.4	80.0
Hungary		10	10		4.8	4.8	4.8	9.6
Italy	10	23	37	5.7	12.1	17.8	20.7	38.5

1962

World Iron Ore Reserves and Resources(1)

	Iron Ore			Iron-In-Ore				
	Geologically Explored Reserves			Geologically Explored Res.				
	Direct Shipping Ore	Concentrating Ore	Potential resources	Direct Shipping Ore	Concentrating Ore	Total Explored	Potential Resources	Total
Europe (Cont'd)								
Luxenbourg		200	70		60.0	60.0	21.0	81.0
Norway	10	222	1,246	5.4	73.9	79.3	424.8	504.1
Poland		315	300		91.1	91.1	92.5	183.6
Rumania	30		70	17.2		17.2	36.0	53.2
Spain	800		300	422.5		422.5	155.2	577.7
Sweden	1,830	370	890	1,164.3	228.5	1,393.3	507.9	1,901.2
Switzerland		36	34		10.0	10.0	9.5	19.5
United Kingdom	2,146		1,160	675.8		675.8	325.3	1,001.1
U.S.S.R	2,801	23,376	16,830	1,549.7	7,696.3	9,246.0	5,571.2	14,817.2
Yugoslavia	32	173	14	11.9	71.1	83.0	7.4	90.4
Total	13,874	27,409	30,606	5,809.4	9,212.3	15,021.7	10,315.7	25,337.4
Asia								
Burma		33			16.7	16.7		16.7
China	789	2,603	7,366	428.2	947.7	1,375.9	3,303.3	4,679.2
Hong Kong		9			3.6	3.6		3.6
India	5,240	84	10,215	3,360.0	33.6	3,393.6	6,555.0	9,948.6
Indochina	40		70	24.7		24.7	42.0	66.7
Indonesia	2		10	1.4		1.4	6.2	7.6
Iran			63				34.2	34.2
Israel		5	10		1.8	1.8	3.5	5.3
Japan	12	41		5.1	18.8	23.9		23.9
Korea		435	1,000		167.3	167.3	260.0	427.3
Malaya		50			28.8	28.8		28.8
Thailand			28				12.6	12.6
Turkey	39		19	24.6		24.6	11.7	36.3
Total	6,122	3,260	18,781	3,844.0	1,218.3	5,062.3	10,228.5	15,290.8

1962

World Iron Ore Reserves and Resources (1)

	Iron Ore			Iron-In-Ore				
	Geologically Explored Reserves			Geologically Explored Res.				
	Direct Shipping Ore	Concentrating Ore	Potential resources	Direct Shipping Ore	Concentrating Ore	Total Explored	Potential Resources	Total
Australasia								
Australia.....	395	100	1,610	255.6	45.0	300.6	907.1	1,207.7
Philippines.....	8	26		4.7	14.4	19.1		19.1
Total	403	126	1,610	260.3	59.4	319.7	907.1	1,226.8
Africa								
Algeria.....	140			75.8		75.8		75.8
Angola.....	148		148	98.4		98.4	98.4	196.8
Egypt.....	15		150	7.5		7.5	75.0	82.5
French Cameroons.....		100			40.0	40.0		40.0
Gabon.....		150	500		63.4	63.4	315.0	378.4
Guinea.....	500		2,100	260.0		260.0	1,170.0	1,430.0
Ivory Coast.....			200				130.0	130.0
Liberia.....	10	90	500	6.6	46.6	53.2	290.0	343.2
Mauritania.....	150			95.3		95.3		95.3
Morocco-French.....	10	30	90	4.6	12.9	17.5	37.8	55.3
Morocco-Spanish.....	15	15	30	9.2	9.2	18.4	18.4	36.8
Rhodesia & Nyasaland.	217			126.0		126.0		126.0
Sierre Leone.....		255			152.6	152.6		152.6
Union of S.Africa....	450	66	800	270.5	36.5	307.0	488.0	795.0
Swaziland.....	59		50	32.2		32.2	32.1	64.3
Tunisia.....	18	1	20	9.9	0.6	10.5	11.0	21.5
Total	1,732	707	4,588	996.0	361.8	1,357.8	2,665.7	4,023.5
WORLD TOTAL	27,615	43,427	98,369	13,964.1	15,077.0	29,041.1	42,128.9	71,170.0

(1) Engineering and Mining Journal, Volume 163, December, 1962.

When we consider these reserves in terms of the demand estimates for 1972-75, with corrections for Communist China, a production life of over 150 years is computed. One may conclude that there will be no world shortage of iron ore in the forseeable future. Moreover the reserves are so distributed throughout the world that no area is geographically remote from several alternate sources of supply.

In the future, the emergence of many underdeveloped countries as major exporters of iron ore is predicted. Integrated iron and steel complexes may develop within their own boundaries, but the immense reserves of high grade iron ore assure a continuing surplus of ore available for export.

Possible Markets for Crest Ore

In recent years the development of super ore carriers have brought most iron ore suppliers within economic marketing range of the United States East Coast, E.C.S.C and Britain, and Japan. One source estimates that the transportation cost per ton on an 8,000 mile voyage decreases with the size of the carrier, as follows:

Liberty size	$8.00
20,000 tonners	$7.00
30/35,000 tonners	$6.50
45/50,000 tonners	$6.00
67,500 tonners	$5.25
100,000 tonners	$4.50

The chart, Iron Ore Prices and Ocean Transportation Rates, on page H-9 graphically compares the competitive relationship of the principal iron ore sources and clearly shows that Japan is the logical market for Snake River ore. In most markets the freight rate is a disadvantage but the ocean freight rate from Haines, Alaska to Japan is lower than from most competing sources. It is also true that shipments from Haines would have a transportation advantage over many other sources in supplying the West Coast of the United States, but this area is now an exporter of ore and the development of a market for imported ore is not imminent.

The following points are critical to the marketing of Crest ore:

1. The location of the Crest deposit requires a large market to overcome the inland transportation problem.

2. The Eastern United States, the E.C.S.C. and Britain, and Japan consume imported iron ore in sufficient quantities to provide this market.

3. There is ample iron ore in the world and there are several competing sources capable of supplying these markets.

4. The ocean shipping rate on Snake River ore delivered in Japan gives Crest an advantage over most of the competing sources of supply which it does not have in the other deficit areas.

5. The West Coast of the United States which has shown rapid economic growth in recent years may eventually require substantial volumes of iron ore and it is possible that Snake River ore could favourably compete.

Export of Iron Ore From Developing Nations to Industrialized Nations, 1950 and 1962

(millions of long tons)

Receiving Area	Latin America		Africa		Asia		Total	
	1950	1962	1950	1962	1950	1962	1950	1962
United States	3.5	15.7	0.7	0.8	-	-	4.2	16.5
Japan	-	5.9	-	0.6	1.3	12.8	1.3	19.3
Britain	-	1.7	3.3	3.3	-	-	3.3	5.0
E.C.S.C.	-	7.3	0.4	5.3	-	2.5	0.4	15.1
Eastern Europe (1)	..	0.8	..	0.7	..	1.6	..	3.1
TOTAL	3.5e	31.4	4.4e	10.7	1.3e	16.9	9.2e	59.0

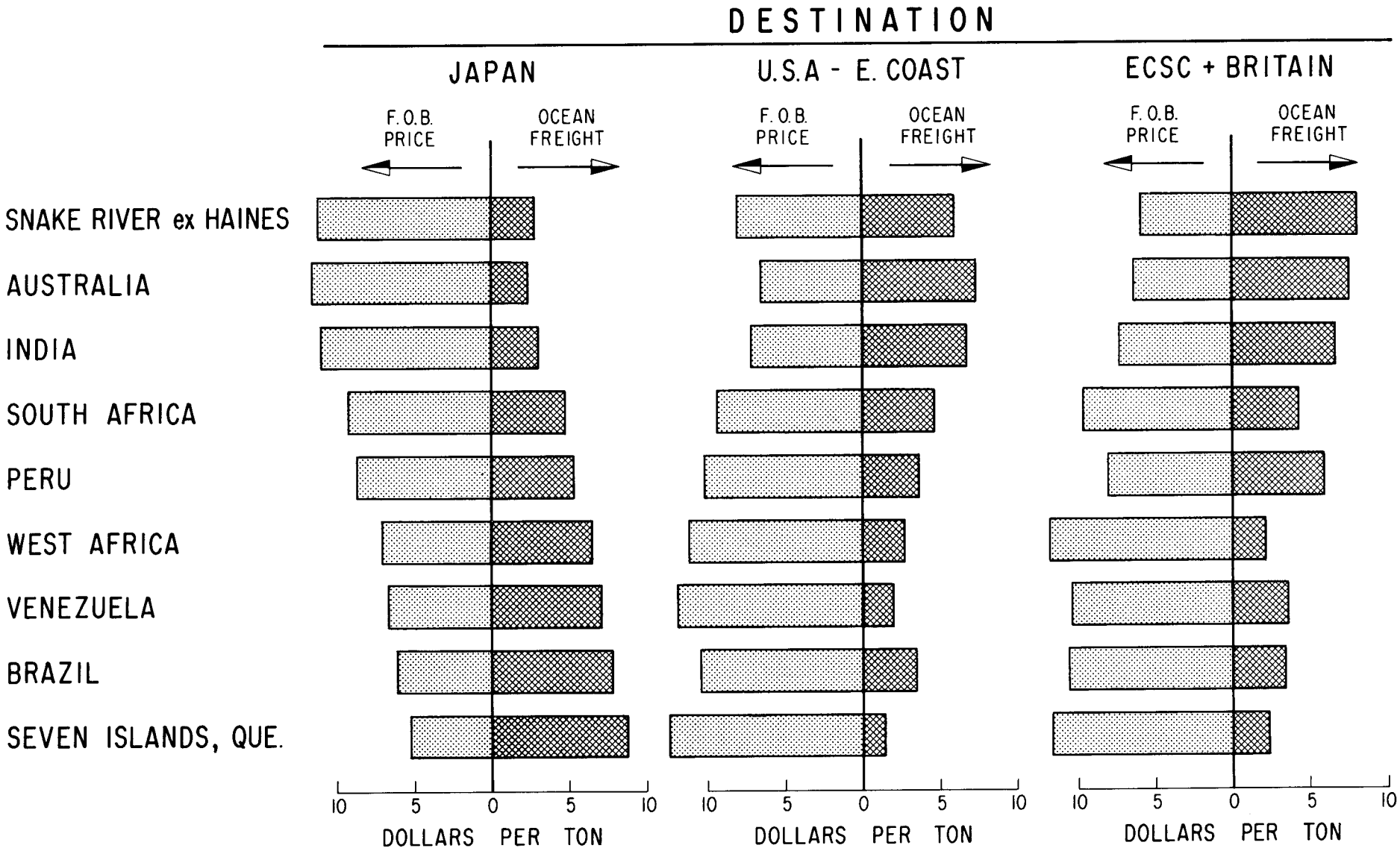
(1) 1961 Data

.. Not available.

- Zero

e Estimate

IRON ORE PRICES AND OCEAN TRANSPORTATION RATES



ASSUMES SHIPMENT IN A SUPER ORE CARRIER OF 69,000 DWT

WEST COAST MARKET

General

The West Coast of the United States has shown a rapid economic growth in the post war years. The prospective population growth and attendant steel consumption in a region which is a deficit steel producer suggested that a substantial iron ore market might develop. However, our investigations of the potential market indicate that this initial conclusion is not justified and that the West Coast of the United States does not offer a large potential market for Snake River ore.

Present Consumption

The 1961 consumption of steel mill products in the seven western states was 6,420,000 net tons of which 57% was produced locally, 33% originated in eastern mills and 10% was imported (mostly from Japan). The pertinent statistics follow:

Seven Western States - 1961 (1)

	Million
Steel Mill Product Shipments:	
Local Mills	3.7
Eastern Mills	2.1
Foreign Imports	0.6
Total (short tons)	6.4
Crude Steel Production (short tons)	5.0 (2)
Pig Iron Production (short tons)	3.3 (3)
Iron Ore Consumption (long tons)	5.3 (4)

(1) Arizona, California, Idaho, Nevada, Oregon, Utah and Washington.

(2) Estimated on the basis of 1.34 T. of crude steel per T. of steel mill products which was the U.S. average in 1961.

(3) Estimated on the basis of the 0.65 T. of pig iron per T. of crude steel which was the experience in the Western States including Colorado.

(4) Estimated on the basis of 1.59 L.T. of ore per T. of pig iron which was the experience in the western states including Colorado. Actual ore consumption is reported at 5.3 million L.T. which includes ore used in steel furnaces.

The principal facilities for production are owned by two companies, Kaiser Steel Corporation at Fontana, California and U.S. Steel Corporation at Geneva, Utah.

Iron and Steel Capacity in Seven Western States
(Million short tons)

	Kaiser & U.S. Steel	Other	Total
Pig Iron	3.8	-	3.8
Open Hearth Steel	4.4	0.3	4.7
Converter Steel	1.4	-	1.4
Electric Steel	-	1.4	1.4
Total Steel	5.8	1.7	7.5

Western mines supplied the local requirements and exported more than 1,700,000 tons of ore to Japan in 1963. It is estimated that these exports will increase to 3,700,000 tons by 1970. Kaiser's mine at Eagle Mountain accounted for most of the exports and the Wabuska and Heizer mines in Nevada provided the remainder.

A comparison of consumption in this area to the United States as a whole shows that the per capita consumption is below the national average.

	Seven Western States	United States
Population (Million)	24.4	183.0
%	13.2%	100.0%
Steel Mill Product Shipments (Million S.T.)	6.4	71.1
%	9.5%	100.0%
Per Capita Consumption (S.T.)	0.26	0.38
%	68%	100.0%

This difference is due to the concentration of heavy industry in the eastern and midwest states. Many of the steel products, such as automobiles, used in the western area are imported as finished goods.

Captive ore is supplied to Kaiser from its mine at Eagle Mountain, California. Columbia Iron Mining Company, a subsidiary of U. S. Steel, owns and operates a number of mines in Iron County, Utah, which have an annual rated capacity of 3.6 million tons. These mines and another at Atlantic City, Wyoming, supply the ore for the Geneva plant.

Future Consumption

In 1975 it is anticipated that the consumption of steel mill products in the seven western states will still be less on a per capita basis than the national average because there is no evidence that any substantial diversion of heavy industry to the West Coast is planned or will occur in the foreseeable future. However, it is expected that the area will produce a greater share of the locally consumed steel mill products and that it will be less dependent on eastern mills and foreign imports. An analysis of probable consumption follows:

	1961	1975
Per Capita Steel Mill Product Consumption as a % of U.S. Average	68%	68%
Population of Area as % of Total U.S. (1)	13.2%	15.4%
Steel Mill Product Consumption as a % of U.S. Demand (2)	9.5%	10.5%
Local Production as a % of Local Demand (3)	57%	75%
In Shipment (Eastern & Foreign Mills) as a % of Local Demand	43%	25%
Iron Ore Consumption Million L.T. (4)	5.5	11.0

(1) Population estimates based on a study by Stanford Research Institute, Population Trends in the United States through 1975.

(2) Estimated at 150 million tons of crude steel. Reference: Long Term Trends and Problems of the European Steel Industry, United Nations 1959. Resources in America's Future, John Hopkins 1963.

(3) Shipments from eastern mills and imports assumed to remain at a constant volume.

(4) Allows for an increase in ore grade from 51% to 62% Fe.

A minimum and maximum estimate were calculated using the same type of analysis. The minimum estimate assumes the 1961 pattern of supply, with per capita consumption of steel mill products at 68% of the national average and with the same portion of the steel demand being supplied by local production. Under these conditions, iron ore requirements are estimated to be 7.9 million long tons. The maximum estimate assumes that heavy industry locates on the West Coast and that the per capita consumption of steel mill products increases to the national average. Under these conditions, it is estimated that 21 million long tons of iron ore would be consumed. However, the realities will probably be somewhere between these limits, with the best estimate at 11 million long tons.

Estimates of iron ore reserves in the western states vary greatly. It can be stated conservatively that sufficient reserves have been established, which are both economic and accessible under current conditions and technology, to meet the median requirements for at least 30 years. Requirements above the local capabilities would, in all probability, be met by captive ore. U. S. Steel, for instance, has reserves in Alaska and Venezuela and Bethlehem has reserves in both Chile and Venezuela. Moreover, South American ore has a price advantage over Snake River ore on the California coast if Japan is taken as the base point for establishing F.O.B. ore prices in the Pacific Basin.

$/Long Ton	San Francisco	Peru	Skagway
C.I.F. Japan	$12.80	$12.80	$12.80
Less: Ocean Freight to Japan	2.90	4.80	2.50
Add: Freight to San Francisco	-	2.60	1.10
C.I.F. San Francisco	$9.90	$10.60	$11.40

In competing for markets on the West Coast, Snake River ore would be at a disadvantage compared to other ores now being shipped to Japan from the west coasts of North and South America. These producers, who now find it economic to produce and supply ore to Japan, could undercut the price of Snake River ore.

The possibility of developing an adequate market for Snake River ore in the seven western states by 1975 is remote. A doubtful market potential, adequate supplies of local ore, and competition from captive or cheaper sources combine to justify this conclusion.

JAPANESE MARKET

Structure of the Japanese Iron and Steel Industry

Iron and Steel Companies

The Japanese iron and steel industry is dominated by large firms. The six largest accounted for nearly 70% of the crude steel production in 1962. There are four other integrated steel companies. eleven non-integrated steel companies operating open hearth furnaces and sixty more manufacturing electric furnace steel.

Crude Steel Production

Fiscal 1961

Company	Million Tons	Percent
Yawata Iron and Steel Co.	6.2	
Fuji Iron and Steel Co.	4.6	
Nippon Kokan Kabushiki Kaisha	3.0	
Kawasaki Steel Corp.	2.6	
Sumitomo Metal Industries	1.7	
Kobe Steel Co.	1.2	
Total	19.3	68
35 Other Makers	6.6	24
Small Producers	2.4	8
GRAND TOTAL	28.3	100

These companies, with the apparent blessing of the Japanese Government, work in close cooperation, particularly in the purchase of raw materials and the export of finished products.

The Japanese Iron and Steel Federation

The Japan Iron and Steel Federation, since its establishment in 1948, has been engaged in widespread research and study to improve the iron and steel industry of Japan. This work has been devoted to raw material acquisition, condition of domestic and overseas markets, changes in steel demand, manufacturing techniques and working conditions of labourers. Particularly noteworthy are the results in the field of public relations and statistical information. The Federation has published many booklets and periodicals in both Japanese and English.

The ultimate objective of the Federation is to foster prosperity within the Japanese iron and steel industry through cooperative study and research. Since the Federation exists for all its members, it does not participate in any individual enterprise, nor do any primary benefits accrue to it for its labours.

Some of the major fields of activity for the Federation in 1962 were: preparing schedules for the production and export of steel and the import of raw materials for making steel, market research of steel products uses, research into the problems of industrial engineering in the steel industry, and extensive research into the conditions of overseas markets. The group has a wider scope of activity than equivalent North American industrial societies. In fact, many of their activities would be considered as restraint of trade in our business world.

The Federation is controlled by the "Big Three" steel companies, Yawata, Fuji and Nippon Kokan.

Government Control

Government control of the Japanese iron and steel industry is exercised through the Heavy Industry Bureau of the Ministry of International Trade and Industry (MITI). MITI's prime function is the control of trade. Its influence reaches far back into the Japanese economy because imports and exports are so important to Japanese industry. Among MITI's general duties are the setting out of investment policies, controlling quantity and quality of production, imposing voluntary export quotas, negotiating trade agreements, administering tariffs and import quotas, negotiating and regulating foreign exchange and investment. Specifically, in the Japanese iron and steel industry, MITI regulates:

1. The open sales system wherein price levels are industry agreed and details of contracts are publicized; the government may suggest alterations in prices or production rates to promote stability;

2. Investment in equipment to prevent unnecessary duplication of facilities;

3. The allocation of foreign exchange for the purchase of machinery, scrap, pig iron, coke and ore, although these restrictions have been relaxed considerably;

4. The modernization of comparatively backward segments of industry by loans and legislation.

Japanese Trading Companies

Trading companies hold a unique position in Japan and have no counterpart in North American practice. One of the special features of Japanese business is that practically all makers and producers, big and small, assign both the selling of their products and the buying of their raw materials at home and abroad to a few powerful general

merchants handling all kinds of commodities. The trading companies provide a liaison between the buyer and seller, arrange shipping, extend credit, negotiate contracts. In addition, these companies often conduct extensive market research for their customers. These trading companies maintain offices throughout the world.

The scope of Japanese trading companies activities is exemplified by the operations of Mitsui and Company. This company is the largest of Japan's trading companies but several competitors are of a similar stature. The 28 departments of its central offices in Tokyo handle more than 3,000 commodities in the industrial, agricultural and consumers categories. To handle transactions with more than 10,000 customers and 3,600 suppliers annually, this global marketing and purchasing agency maintains 33 offices and 7 representatives in Japan and 35 offices and 42 representatives in 48 foreign countries. More than 15% of its 8,967 employees work overseas.

Frequently foreign manufacturers establish factories in Japan in conjunction with trading companies and trading companies are increasingly engaging in joint ventures abroad.

The following excerpt is taken from a report on the visit of W. K. Kiernan, B.C. Minister of Mines, C.H. Mitchell, Sec. Treas. B.C. Mining Association, B.O. Brynelsen of Noranda Exploration Ltd., to Japan. The comments are based on a meeting with Yawata and Fuji Iron and Steel Companies at which A. Ojima, Chairman of Yawata and S. Nagano, President of Fuji, were present.

> "Generally speaking, contracts for the supply of iron ore are negotiated between the raw material supplier on one hand, and the Japanese steel industry on the other. The industry is usually represented in these negotiations by one of the "big three" companies - Yawata, Fuji or Nippon Kokan. Usually, the company which has had the widest experience with, and enjoys the best contacts in the raw materials source country, is appointed as "coordinator" at a previous meeting of representatives of whole industry. Once a contract is concluded, the coordinating steel company nominates the trading companies who will handle the business and allocate tonnages to each of these trading companies on behalf of the various steel mills participating in the total importation provided for in the contract.
>
> Apart from the services of introducing new raw materials sources to the industry, the functions of the trading companies include such services as opening letters of credit in favour of suppliers on behalf of the end-user mills, setting up freight charters, and generally arranging for the financing of the delivery of the ore to the mills. For these services, the trading companies earn a commision of "X" yen per ton which will vary with the total tonnage of the material involved.
>
> As far as purchase of iron ore from North America is concerned, Fuji Iron and Steel Co. has played the leading role as the industry coordinator followed by Yawata and Nippon Kokan. The designated trading companies in the past have been Kishimoto Shoten, Kinoshita, Mitsubishi Shoji and the Gosho Co. for North American iron ore."

At the outset, Crest was besieged by numerous Japanese trading companies offering to be our agents in Japan. During operations we have maintained close contact with all of the companies showing an interest in Crest and have released periodic progress reports on our project. In return we have been receiving up-to-date information on the Japanese iron ore market.

The policy of Crest in respect to trading companies may be stated as one of non-alignment. We have been very careful to accord equal treatment to all.

Japanese Demand for Imported Iron Ore

The Income Doubling Plan and Ore Requirements

To satisfy the rapidly expanding demand, Japan will have to increase imports of iron ore by 2.7 million metric tons every year between 1963 and 1970, a total increase of 19 million metric tons in 7 years. This exceptionally high rate of increase is a consequence of rapid growth within the economy, technological changes within the steel industry and the inability of domestic production to maintain its share of demand.

Japanese Imported Iron Ore
Million metric tons

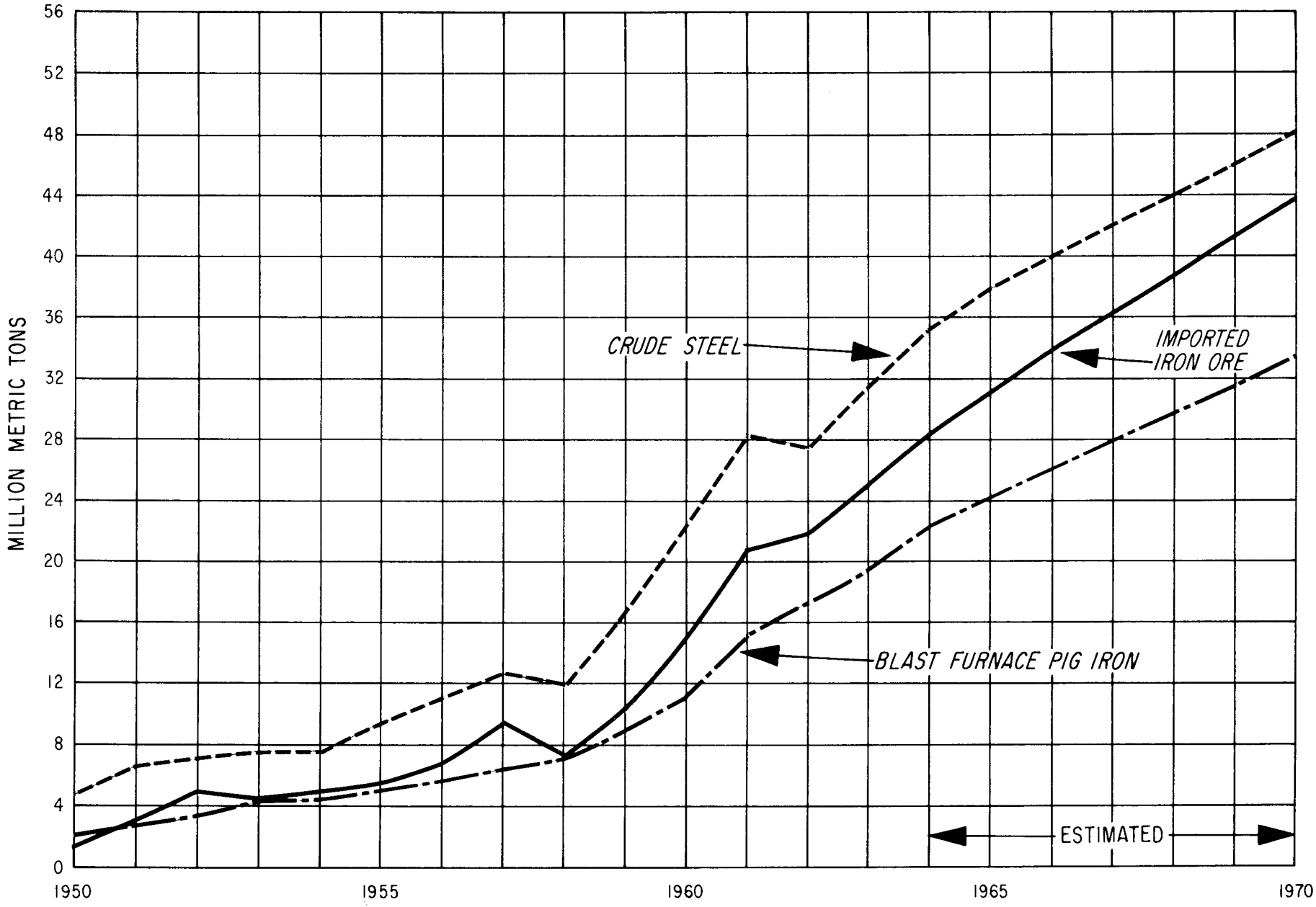
Year	Imports
1963	24.7
1964	28.6
1965	31.4
1966	33.8
1967	36.3
1968	38.8
1969	41.3
1970	43.8

The chart, Japan, Imports of Iron Ore and Production of Pig Iron and Crude Steel on page H-18 graphically depicts the actual and forecast growth between 1950 and 1970.

In December of 1960, the Japanese Government approved a "New Long-Range Economic Plan of Japan" which set an objective of doubling the nation's income between 1960 and 1970. Although this plan appears to be extremely amitious, it is worth noting that the growth between 1950 and 1960 was more than double, 2.4 times. Earlier growth rates were also high, an annual rate of 11.5% between 1947 and 1952 and 8.3% between 1953 and 1959, which are both above the growth rate of 6.5% set by the government in establishing this plan. The rate of growth for the first three years under the plan will probably be 10% even after the slow down in 1962. It appears very likely that the Japanese will attain their goal by 1970.

JAPAN

IMPORTS OF IRON ORE, PRODUCTION OF PIG IRON AND CRUDE STEEL



Iron and Steel Production

Our particular interest is in the iron and steel industry where the plan estimates a crude steel production of 48 million metric tons in 1970.

Production of iron and steel in Japan has recorded a fantastic growth rate in the post war years; between 1950 and 1963 crude steel production increased at an average rate of 15% per annum and pig iron at 19%. Although there has been some slow down in recent years with these rates falling to 12% and 18% respectively between 1960 and 1963, the growth rates still far exceed the 8% and 11% predicted under the economic plan.

The increased demand for steel can be attributed to both the domestic and export market. There has been a rapid growth in both sectors but domestic demand accounts for approximately three-quarters of the increased production.

Supply of Crude Steel
In Terms of Crude Steel Equivalent
Million Metric Tons

	Production	Imports	Exports	Home Supply
1956	11.1	0.3	1.7	9.7
1963	31.5	0.1	7.2	24.4

Since the estimated production increase is based largely upon increased domestic consumption, one can put more faith in the estimates than if they were based upon increases in exports to a competitive world market.

Demand for Iron Ore

From the wealth of information released by the Japanese government and steel industry on their plans for attaining a goal of 48 million tons of crude steel production by 1970, the demand for iron ore is readily predictable. The table, Japan's Iron and Steel Industry on page H-20, shows that the estimated 1970 requirement for iron ore in Japan is 56 million tons, of which 44 million tons will be imported.

The demand for imported iron ore is expected to increase more rapidly than both steel and pig iron. This results from technological changes within the Japanese steel industry.

Increase in Crude Steel, Pig Iron and Iron Ore

	1970/1960	Million Metric Tons
Crude Steel	2.17 times	up 25.9
Pig Iron	2.94 times	up 23.1
Total Iron Ore	2.77 times	up 35.9
Domestic Iron Ore	1.69 times	up 5.5
Imported Iron Ore	3.26 times	up 30.4

Japan's Iron and Steel Industry
Million Metric Tons

		Actual			Estimated	
		1950	1955	1960	1965	1970
Iron and Steel Output						
Pig Iron:	Blast Furnace	2.0	5.0	11.3	24.4(2)	33.5(1) (2)
	Other	0.2	0.2	0.6	1.0(3)	1.5(1)
	Total	2.2	5.2	11.9	25.4(2)	35.0(1)
Crude Steel:	Open Hearth	3.9	7.8	15.0	12.8(3)	14.5(1)(2)
	Converters	0.2	0.4	2.6	17.7(3)	25.0(1)(2)
	Electric Furnace	0.8	1.2	4.5	7.5(3)	8.5(1)(2)
	Total	4.9	9.4	22.1	38.0(2)	48.0(1)(2)
Raw Material Supply						
Iron Ore:	Domestic	1.7	4.3	6.6	9.5(2)	12.1(2)
	Imported	1.8	5.2	13.4	31.4(2)	43.8(2)
	Total	3.5	9.5	20.0	40.9(2)	55.9(2)
Scrap:	Domestic	NA	5.3	9.3	15.2(3)	22.0(1)
	Imported	NA	1.3	4.4	4.8(3)	3.5(1)
	Total	4.3	6.6	13.7	20.0(3)	25.5(1)

(1) MITI Goal - Double the National Income Objective

(2) Japanese Steel Mills, January 1964.

(3) Crest Estimate

These different growth rates are a consequence of trends within the Japanese steel industry.

1. The relationship between crude steel and pig iron is dependent upon the scrap of pig iron ratio used in steel furnaces. For different processes, the proportion changes. The table, Production of Crude Steel and Input of Pig Iron and Scrap, shown on page H-22 illustrates this point.

   The Japanese plan for steel production in 1970 as compared to 1960 is as follows:

	1960 Pig Iron as a % of Feed	% of Steel Production 1960	1970
Open Hearth	55	68	30
Converter	80	12	52
Electric Furnace	3	20	18
		100	100

   The emphasis on converters with their high proportion of pig iron feed will result in pig iron (and consequently iron ore) requirements growing more rapidly than crude steel production.

   The installation of the relatively new L.D. type converters is well under way in Japan, with converter steel production having increased from 2.6 to 12 million tons between 1960 and 1963. This process produces high quality steel at lower cost than the open hearth and it has the added advantage of reducing the dependency on imported scrap which is subject to wide fluctuation in price.

2. Since iron ore requirements are related to pig iron production, t there is a strong similarity in growth rates. However, the ore being fed to Japanese blast furnaces is becoming higher in iron content, so that the tonnage of iron ore required will not grow as rapidly as pig iron production. The table, Production of Pig Iron and Iron Ore Requirements on page H-23, shows this change.

3. Imported iron is growing more rapidly than total requirements because Japan's domestic producers are unable to increase their production sufficiently to maintain their position.

Japan

Production of Crude Steel and Input of Pig Iron and Scrap
Million Metric Tons

	1950	1955	1960	1961	1962	1963	1965	1970
Prod. of Crude Steel	4.8	9.4	22.1	28.3	27.5	31.5	38.0	48.0
Open Hearth	3.9	7.8	15.0	17.0	13.3	12.2	12.8	14.5
Converter	0.2	0.4	2.6	5.4	8.4	12.0	17.7	25.0
Electric	0.7	1.2	4.5	5.9	5.8	7.3	7.5	8.5
Crude Steel Input								
O-H Input as % Yield	113	110	112	112	111		111	111
O-H Pig Scrap Ratio	.53:1	.91:1	1.21:1	1.30:1	1.74:1		1.74:1	1.74:1
O-H Pig Input	1.5	4.1	9.2	10.8	9.4		9.0	10.2
O-H Scrap Input	2.9	4.5	7.6	8.3	5.4		5.2	5.9
O-H Total	4.4	8.6	16.8	19.1	14.8		14.2	16.1
Conv.Input as % Yield	111	110	110	110	110		110	110
Conv.Pig Scrap Ratio	-	-	3.83:1	3.54:1	4.17:1		4:17.1	4.17:1
Conv.Pig Input	2.2	.4	2.3	4.6	7.5		15.7	22.2
Conv.Scrap Input	-	-	0.6	1.3	1.8		3.8	5.3
Conv. Total	2.2	.4	2.9	5.9	9.3		19.5	27.5
Elect.Input as % Yield	112	110	108	109	108		108	108
Elect.Pig Scrap Ratio	-	-	.036:1	.040:1	.035:1		.025:1	.022:1
Elect.Pig Input	-	-	0.1	0.3	0.2		0.2	0.2
Elect.Scrap Input	0.8	1.3	4.7	6.2	6.1		7.9	9.0
Elect. Total	0.8	1.3	4.8	6.5	6.3		8.1	9.2
Steel Input % Yield	112	110	111	111	111		110	110
Steel Pig Input	1.7	4.5	11.6	15.7	17.1		24.9	32.6
Steel Scrap Input	3.7	5.8	12.9	15.8	13.3		16.9	20.2
Steel Total Input	5.4	10.3	24.5	31.5	30.4		41.8	52.8
Input Kg/T Crude Steel								
Pig	354	479	525	536	622		655	679
Scrap	771	617	584	558	484		445	421
Total	1125	1096	1109	1094	1106		1100	1100

Japan

Production of Pig Iron & Iron Ore Requirements
(Million Metric Tons)

	Pig Iron			Iron Ore				
	Blast Furnace	Other Furnace	Total	Total Consumption	Ore/T. B.F. Pig	Supply Domestic*	Supply Imported	Supply Total
1950	2.0	0.2	2.2	3.5	1.75	1.7	1.4	3.1
1951	2.9	0.2	3.1	5.3	1.83	2.0	3.1	5.1
1952	3.3	0.2	3.5	6.0	1.82	2.7	4.8	7.5
1953	4.3	0.2	4.5	7.5	1.74	3.4	4.3	7.7
1954	4.4	0.2	4.6	8.4	1.91	3.7	5.0	8.7
1955	5.0	0.2	5.2	9.5	1.90	4.2	5.5	9.7
1956	5.7	0.3	6.0	11.0	1.93	4.5	7.8	12.3
1957	6.4	0.4	6.8	12.4	1.94	5.0	9.4	14.4
1958	7.0	0.4	7.4	13.0	1.86	5.4	7.6	13.0
1959	8.9	0.5	9.4	16.0	1.80	5.8	10.4	16.2
1960	11.3	0.6	11.9	19.8	1.75	6.6	14.8	21.4
1961	15.0	0.8	15.8	26.3	1.75	7.6	20.9	28.5
1962	17.4	0.6	18.0	29.6	1.70	7.8	22.2	30.0
1963	19.4	0.5	19.9	32.7	1.69	8.0	24.7	32.7
1964	22.4(2)			37.6(2)	1.68	9.0(2)	28.6(2)	37.6(2)
1965	24.4(2)	1.0(3)	25.4(3)	40.8(2)	1.67	9.5(2)	31.4(2)	40.9(2)
1966	26.2(2)			43.9(2)	1.67	10.1(2)	33.8(2)	43.9(2)
1967	28.1(2)			46.9(2)	1.67	10.6(2)	36.3(2)	46.9(2)
1968	29.9(2)			49.9(2)	1.67	11.1(2)	38.8(2)	49.9(2)
1969	31.7(2)			52.9(2)	1.67	11.6(2)	41.3(2)	52.9(2)
1970	33.5(1)(2)	1.5(1)(2)	35.0(1)(2)	55.9(2)	1.67	12.1(2)	43.8(2)	55.9(2)

(1) MITI Goal
(2) Japanese Steel Mills, January 1964.
(3) Crest Estimate

* Includes iron ore, iron sand, pyrite sinters and other ferrous material

Japan

Production of Crude Steel
(Million Metric Tons)

Year	Open Hearth	Converter	Electric	Total
1950	3.9	0.2	0.7	4.8
1951	5.4	0.2	0.9	6.5
1952	5.8	0.2	0.9	6.9
1953	6.3	0.3	1.0	7.6
1954	6.4	0.4	1.0	7.8
1955	7.8	0.4	1.2	9.4
1956	9.0	0.4	1.7	11.1
1957	9.9	0.5	2.2	12.6
1958	9.2	0.8	2.1	12.1
1959	12.3	1.2	3.1	16.6
1960	15.0	2.6	4.5	22.1
1961	17.0	5.4	5.9	28.3
1962	13.3	8.4	5.8	27.5
1963	12.2	12.0	7.3	31.5
1964				35.3(2)
1965	12.8(3)	17.7(3)	7.5(3)	38.0(2)
1966				40.0(2)
1967				42.0(2)
1968				44.0(2)
1969				46.0(2)
1970	14.5(2)	25.0(2)	8.5(2)	48.0(1)(2)

(1) MITI Goal

(2) Japanese Steel Mills, January 1964.

(3) Crest

Japan

Pig Iron Supply and Demand
Million Metric Tons

	1950	1955	1960	1961	1962	1963	1965	1970
Production:								
Blast Furnace	2.0	5.0	11.3	15.0	17.4	19.4	24.4	33.5
Other	0.2	0.2	0.6	0.8	0.6	0.5	1.0	1.5
Total	2.0	5.2	11.9	15.8	18.0	19.9	25.4	35.0
Imports	-	-	1.0	2.1	1.5	1.6	2.3	0.5
Exports	-	0.1	-	-	-	-	-	-
Domestic Supply	2.0	5.1	12.9	17.9	19.5	21.5	27.7	35.5
Steel Requirements	1.7	4.5	11.6	15.7	17.1	18.7	24.9	32.6
Pig to Foundry Inv.Loss & Adjust.	0.3	0.6	1.3	2.2	2.4	2.8	2.8	2.9

Scrap Supply and Demand(1)
Million Metric Tons

	1950	1955	1960	1961	1962	1963	1965	1970
Supply:								
Purchased	NA	2.6	3.8	4.7	4.3)	12.0	15.2	22.5
Returned	NA	2.7	5.5	6.7	6.4)			
Imported	NA	1.3	4.4	7.0	3.6	3.5	4.8	3.0
Total	4.3	6.6	13.7	18.4	14.3	15.5	20.0	25.5
Consumption:								
Pig Iron	0.6	0.2	0.3	0.4	0.3	NA	0.5	0.8
Steel	3.7	5.8	12.9	15.8	13.3	NA	16.9	20.2
Total	4.3	6.0	13.2	16.2	13.6	15.1	17.4	21.0

(1) In 1970, MITI estimates the volume of scrap at 25.5 million metric tons which seems high in comparison to our analysis. However, we believe that this estimate includes scrap which is used by foundries and that the historical data 1950-1963 does not include this supply. In 1961 and 1962 foundry use of scrap is reported at over 2 million tons.

Japanese Sources of Imported Iron Ore

General Pattern of Supply

Japan's limited supply of domestic iron ore is supplemented by iron sand and pyrite sinter. Nevertheless, the volume of domestic blast furnace feed is small in relation to overall requirements and the dependency on imported iron ore has increased rapidly in the past decade.

Japanese Iron Ore Supply
Million Metric Tons

	1953	1963(1)	1970(3)
Domestic			
Iron Ore	1.1	1.1	
Iron Sand	0.6	1.4	
Pyrite Sinter	0.9	1.9	
Other (2)	0.8	2.6	
Total Domestic	3.4	8.0	12.1
Imported Iron Ore	4.3	24.7	43.8
Total Supply	7.7	32.7	55.9

(1) Calendar Year
(2) Flue dust, furnace scale, etc.
(3) Japanese steel mills, January 1964.

In the latter part of the nineteen fifties there was concern in Japan about the reserves of iron ore within the Pacific Basin and Japan was keenly interested in establishing assured sources. Subsequent discoveries have reversed the situation and there is now no shortage of iron ore. In addition, super ore carriers can now competitively deliver to Japan ores which were formerly outside the economic sphere of supply.

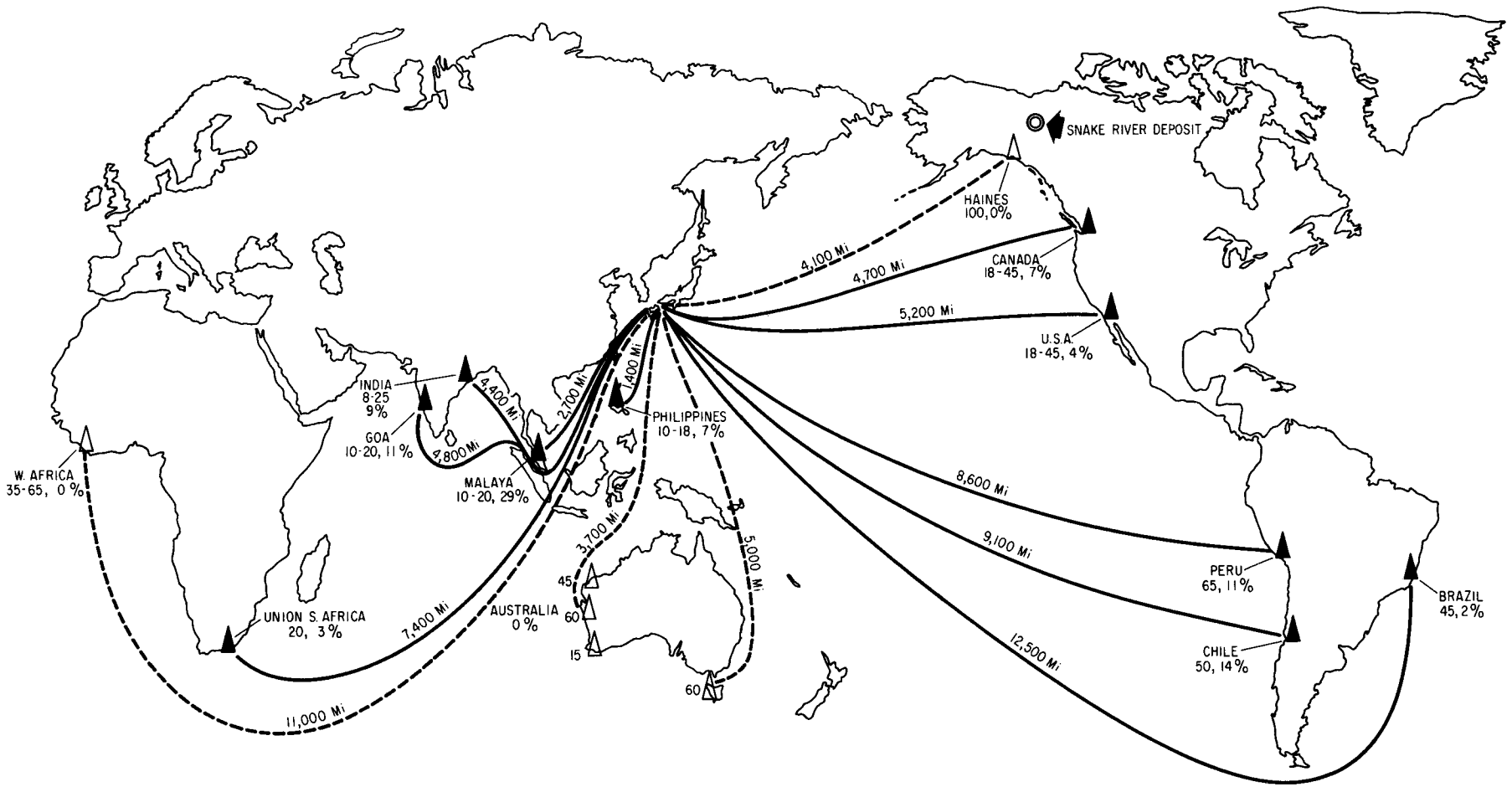
In 1963 Japan purchased ore in over thirteen different countries. As the requirements for iron ore have increased, Japan has gone further afield to secure supplies. The map, Japanese Sources of Iron Ore, on page H-27 shows the wide distribution of Japanese iron ore purchases in 1962 and the following table records 1963 purchases:

Japanese Imported Iron Ore
Fiscal 1963* Million Metric Tons

Philippines	1.4	U.S.A.	1.9
Malaya	6.3	Brazil	0.5
India	2.3	Peru	3.1
Goa	3.8	Chile	3.6
Hong Kong	0.1	Africa	1.1
Korea	0.7	Others	0.5
Canada	1.8		
		Total	27.1

* April to March

JAPANESE SOURCES OF IRON ORE



▲ —— EXISTING SUPPLY ROUTES

△ - - - - POTENTIAL SUPPLY ROUTES

CANADA 18-45, 7% — 18-45 — PORT CAPACITY OR SIZE OF CARRIER OPERATING FROM THIS PORT IN THOUSANDS OF DWT's

7% — PERCENTAGE OF JAPANS IMPORTS, 1962

MARCH 20, 1964

The steel industry, cognizant of its dependency on imported ore, is constantly studying sources of iron ore and dispatching investigating teams to report on new deposits.

Future Suppliers

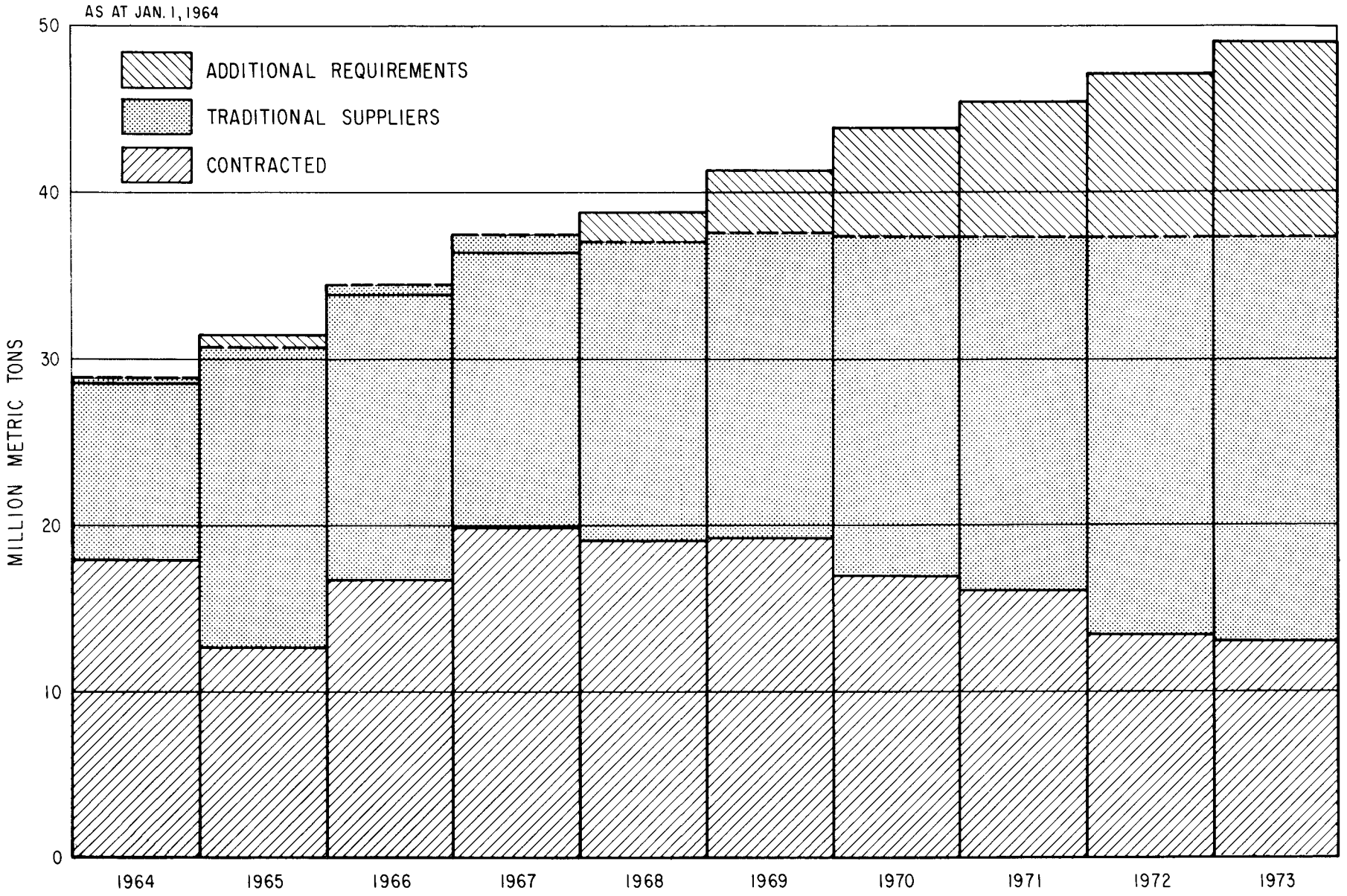
The Japanese, although intent on securing the best quality ore at the lowest prices, also distribute their purchases in such a way as to promote exports. The economy of supply is not the sole determining factor in Japanese ore purchases. Japan's economic growth is related to her international trade and it is indeed unlikely that Japanese ore purchases would be concentrated in any manner that would be detrimental to the export program. Japan's policy is one of spreading ore purchases in foreign countries to receive the maximum benefit of reciprocal trade, while at the same time purchasing ore as cheaply as possible. By diversifying supply sources, the Japanese steel industry is also able to minimize the effects of political disturbances on ore deliveries and to gain the price advantages accruing from competition between supplier countries.

Predictions of the patterns of future supply are hazardous at best. However, by studying current contracts, past purchases and plans announced by the Japanese mills, a supply in relation to total demand has been established and is shown in the chart, Estimated Japanese Iron Ore Imports. This chart shows that by 1973 Japan will require about 12 million metric tons of iron ore over and above the volume which is now contracted or is apt to be supplied by mines which are regular suppliers to Japan. The tabulation on page H-32 presents a summary of the estimates by contracts, traditional suppliers, mines and country.

In this tabulation three large volume long term contracts are chiefly responsible for the increase in ore classified as firm supply. It is anticipated that India will increase its exports to Japan by 6 million tons per annum under two contracts, one at Bailadila by 4 million t.p.a. and the other at Rourkela by 2 million t.p.a. These contracts were engotiated in 1958 but extensive development was needed to prepare for production which started in 1964 and is scheduled to grow to 6 million t.p.a. by 1967. Japan is assisting India in the development of these projects by advancing credit grants for the purchase of Japanese machinery. A contract with Brazil provides the other major increase with imports scheduled to increase from 450,000 t.p.a. in 1964 to 4,000,000 t.p.a. in 1973. There are a number of other smaller contracts which will either come into force or grow to their maximum during this period but these will be counter-balanced by a decrease in shipments from Malaya resulting from depletion of many of the smaller mines.

Japanese purchasers of iron ore are now besieged by numerous offers from iron ore producers, particularly from those developing Australian reserves. The following tabulation summarizes the offers which we believe are seriously being considered.

ESTIMATED JAPANESE IRON ORE IMPORTS



NOTE: The projected consumption to 1970 is from data published by the Japanese Ministry of International Trade and Industry. The contract data is from published Japanese sources.

Summary of New Contract Offers to the Japanese Steel Industry
Million Metric Tons

Source	1971	Remarks
Australia	20.5	Represents total offers from 7 different companies, with deliveries commencing in 1965 and building up to maximum indicated. 5 million tons are pellets.
U.S.A.	1.8	Represents total offers from 2 companies for pellets. 800,000 tons are in the stage of being contracted.
Canada	1.0	1 company offer, current literature reports price being negotiated before conclusion of contract.
Philippines	0.8	1 company, pellets.
Total	24.1	Varying delivery dates commencing 1965.

In addition to these offers, there are a number of other sources willing to supply ore to Japan whose offers have been refused. Japanese delegations have also discussed the purchase of Hainan ore from Red China and a recent news release suggests that an import of 1 million tons is being considered for 1965. This import would probably be a barter arrangement.

The Australian offers are being actively negotiated. The Japanese steel industry has arranged for a survey team, representing the 10 major steel mills, to visit Australia in June of 1964. There is little doubt that the Japanese will eventually sign contracts for some Australian ore. However, their policy of diversifying their iron ore purchases for reasors of trade will impose some limitation on the volume that can be taken from Australia.

Projected 1970 Imports of Iron Ore
Million Metric Tons

Country	1964	1970 Firm*	1970 Anticipated	1970 Total
Philippines	1.4	1.7	0.8(1)	2.5
Malaya	6.4	3.7	-	3.7
Other Far East	0.7	0.7	-	0.7
India	2.5	8.5	-	8.5
Goa	4.4	4.8	-	4.8
Canada	1.9	1.6	1.0(2)	2.6
U.S.A.	1.9	2.9	0.8(3)	3.7
Chile	4.2	3.8	-	3.8
Peru	4.1	3.7	-	3.7
Brazil	0.5	3.0	-	3.0
Africa	1.0	2.4	-	2.4
Australia	-	0.7	5.0(4)	5.7
Total	29.0	37.5	7.6	45.1
Demand	28.6			43.9

* Firm, contracted and assumed on basis of past experience and estimates of 10 leading Japanese steel companies.

(1) Larap Pellet now under negotiation.
(2) Tassoo sinter and fines under negotiation and reported being finalized.
(3) Eagle Mountain pellet, additional supply reported contracted.
(4) Anticipated contracts from numerous offers.

In assessing our projections of future supply, it should be realized that a large portion included as firm supply is not under contract, 27.1 million tons in 1970 and 35.9 million tons in 1973. In preparing this projection it has been assumed that contracts will be extended and that deliveries of ore from major suppliers will be continued even though the current contracts expire in the period under review. Also included is a substantial amount of ore which is ordinarily contracted on an annual basis as in the Philippines, Malaya and Goa. Therefore, there is a possibility, under certain conditions of quality, price, trade and political disturbance, for other producers of iron ore to displace substantial volumes of supply which has been classified as firm.

JAPANESE SOURCES OF IRON ORE

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Philippines	1417	1420	1730	1730	1730	1730	1730	1730	1730	1730	1730
Malaya	6700	6400(4020)	5560	4810	4710	4280	3680	3680	3680	3680	3680
Other Far East	527	720	720	720	720	720	720	720	720	720	720
India	2803	2450(2450)	4450(2000)	6450(4000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)
Goa	2998	4350(1600)	4150(650)	4600(1450)	4700(1450)	4700(700)	4800(700)	4800(700)	4800(700)	4800	4800
Canada	1886	1850(1850)	1970(1680)	1970(1680)	1930(1640)	1890(1600)	1770(1200)	1600(500)	1600(500)	1600(500)	1600(500)
U.S.A.	1821	1900(1800)	2150(1650)	2900(2400)	2900(2400)	2900(2400)	2900(2400)	2900(2400)	2900(2000)	2900(500)	2900
Chile	3118	4150(3450)	3850(3250)	3850(2750)	3750(2650)	3750(2650)	3750(2550)	3750(1650)	3750(1650)	3750(1150)	3750(400)
Peru	2951	4100(1975)	3650(1625)	3650(1625)	3650(1625)	3650(1625)	3650(1200)	3650(400)	3650	3650	3650
Brazil	498	450(450)	600(600)	1000 (1000)	2000(2000)	2000(2000)	3000(3000)	3000(3000)	3000(3000)	3000(3000)	4000(4000)
Africa	700	1000(400)	1890(1290)	2190(1340)	2350(1500)	2350(1500)	2350(1500)	2350(1500)	2350(1500)	2350(1500)	2350(1500)
Australia	-	-	-	500(500)	550(550)	600(600)	650(650)	700(700)	700(700)	700(700)	700(700)
Other	556										
Total	25975	28790(18025)	30720(12745)	34370(16745)	37430(19815)	37020(19075)	37450(19200)	37330(16850)	37330(16050)	37330(13350)	37330(13100

( ) Denotes Contracted

Thousand Metric Tons

As of January, 1964

JAPANESE IRON ORE IMPORTS

BY MINE AND COUNTRY

( ) Denotes Contracted

		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
PHILIPPINES	Larap	770	800	750	750	750	750	750	750	750	750	750
	Sibuguey	400	500	500	500	500	500	500	500	500	500	500
	Pagadian	-	120	120	120	120	120	120	120	120	120	120
	Pioneer	-	-	360	360	360	360	360	360	360	360	360
	Mati	80										
	Total	1250	1420	1730	1730	1730	1730	1730	1730	1730	1730	1730
MALAYA	Dungun	2700	(2200)	2000	2000	2000	2000	1500	1500	1500	1500	1500
	Rompin	1400	(1700)	1500	1500	1500	1500	1500	1500	1500	1500	1500
	Temangan	80	480	550	550	550	200	200	200	200	200	200
	Sri Medan	260	300	250	-	-	-	-	-	-	-	-
	MMC	100	150	150	-	-	-	-	-	-	-	-
	FEMCO	340	400	400	400	400	400	400	400	400	400	400
	Bedong	80	120	100	-	-	-	-	-	-	-	-
	Cha'ah	110	90	-	-	-	-	-	-	-	-	-
	Ulu-Yam	-	50	50	-	-	-	-	-	-	-	-
	Kemaman	50	80	80	80	80	80	80	80	80	80	80
	Kedah	170	250	100	-	-	-	-	-	-	-	-
	Pontian	120	(120)	-	-	-	-	-	-	-	-	-
	Tui	70	160	100	100	-	-	-	-	-	-	-
	BRIMCO	120	120	100	-	-	-	-	-	-	-	-
	Susur Rotan	-	80	80	80	80	-	-	-	-	-	-
	Other	312	100	100	100	100	100	-	-	-	-	-
	Total	5912	6400(4020)	5560	4810	4710	4280	3680	3680	3680	3680	3680
OTHER FAR EAST	Hong Kong	120	120	120	120	120	120	120	120	120	120	120
	Thailand	-	100	100	100	100	100	100	100	100	100	100
	Korea	680	500	500	500	500	500	500	500	500	500	500
	Total	800	720	720	720	720	720	720	720	720	720	720

Thousand Metric Tons

As of January, 1964.

JAPANESE IRON ORE IMPORTS

BY MINE AND COUNTRY

( ) Denotes Contracted

		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
INDIA	Basic Grade	2200	(2000)	2000	2000	2000	2000	2000	2000	2000	2000	2000
	High Grade	220	(300)	300	300	300	300	300	300	300	300	300
	Low Grade	120	(150)	150	150	150	150	150	150	150	150	150
	Rourkella	-	-	(2000)	(2000)	(2000)	(2000)	(2000)	(2000)	(2000)	(2000)	(2000)
	Balidilla	-	-	-	(2000)	(4000)	(4000)	(4000)	(4000)	(4000)	(4000)	(4000)
	Total	2540	2450(2450)	4450(2000)	6450(4000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)	8450(6000)
GOA	Chowgule	580	1000(700)	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Sacorda	230	200	200	200	200	200	200	200	200	200	200
	V.S. Dempo	620	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Shantilal	961	1200(900)	1200(650)	1200(950)	1300(950)	1300(200)	1400(200)	1400(200)	1400(200)	1400	1400
	Agrawal	240	150	200	200	200	200	200	200	200	200	200
	Salgaocar	350)	800	550	500	500	500	500	500	500	500	500
	Others	465)										
	Chowgule Pellet	-	-	-	(500)	(500)	(500)	(500)	(500)	(500)	500	500
	Total	3446	4350(1600)	4150(650)	4600(1450)	4700(1450)	4700(700)	4800(700)	4800(700)	4800(700)	4800	4800
CANADA	Nimpkish	350	-	-								
	Texada	450	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)
	Lake Kennedy	700	(700)	(700)	(700)	(700)	(700)	(700)	700	700	700	700
	Quatsino	100	-	-	-							
	Zeballos	-	(170)	290	290	290	290	170				
	Jedway	300	(400)	(400)	(400)	(400)	(400)	400	400	400	400	400
	Cominco	-	(80)	(80)	(80)	(40)						
	Total	1900	1850(1850)	1970(1680)	1970(1680)	1930(1640)	1890(1600)	1770(1200)	1600(500)	1600(500)	1600(500)	1600(500)
U.S.A.	Wabuska	300	(400)	(400)	(400)	(400)	(400)	(400)	(400)	400	400	400
	O.C. Nevada	400	500(400)	500	500	500	500	500	500	500	500	500
	Eagle Mtn.	1000	(1000)	(1000)	(1000)	(1000)	(1000)	(1000)	(1000)	(1000)	1000(500)	1000
	Eagle Mtn.Pellet			(250)	(1000)	(1000)	(1000)	(1000)	(1000)	(1000)	1000	1000
	Total	1700	1900(1800)	2150(1650)	2900(2400)	2900(2400)	2900(2400)	2900(2400)	2900(2400)	2900(2000)	2900(500)	2900

Thousand Metric Tons

As of January, 1964.

JAPANESE IRON ORE IMPORTS

BY MINE AND COUNTRY

		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
CHILE	Algarobo	1439	1500(1250)	1300(1250)	1300(1250)	1300(1250)	1300(1250)	1300(1250)	1300(1250)	1300(1250)	1300(750)	1300
	Romeral	600	(700)	(500)	500	500	500	500	500	500	500	500
	Adrianitas	400	500(400)	600(400)	600(400)	600(400)	600(400)	600(400)	600(400)	600(400)	600(400)	600(400)
	Santa Fe	900	1250(900)	1250(900)	1250(900)	1250(900)	1250(900)	1250(900)	1250	1250	1250	1250
	Cominex	100	(100)	100	(100)	(100)	(100)	100	100	100	100	100
	Philbro	100	(100)	100	(100)							
	El Tofo	80										
	Total	3619	4150(3450)	3850(3250)	3850(2750)	3750(2650)	3750(2650)	3750(2550)	3750(1650)	3750(1650)	3750(1150)	3750(400)
PERU	Marcona	2054	2500(1625)	2500(1625)	2500(1625)	2500(1625)	2500(1625)	2500(1200)	2500(400)	2500	2500	2500
	Marcona Pellet	35	600	800	800	800	800	800	800	800	800	800
	Acari	813	1000(350)	350	350	350	350	350	350	350	350	350
	Sta Barbra	27	-	-	-	-	-	-	-	-	-	-
	Total	2929	4100(1975)	3650(1625)	3650(1625)	3650(1625)	3650(1625)	3650(1200)	3650(400)	3650	3650	3650
BRAZIL	Itibra	420	(450)	(600)	(1000)	(2000)	(2000)	(3000)	(3000)	(3000)	(3000)	(4000)
SOUTH AFRICA	Postmasburg	573	600	600	600	600	600	600	600	600	600	600
RHODESIA	Beacon Tor	100	(100)	(140)	(140),	(300)	(300)	(300)	(300)	(300)	(300)	(300)
SWAZILAND	Bomvu Rioge	-	(300)	(1150)	1450(1200)	1450(1200)	1450(1200)	1450(1200)	1450(1200)	1450(1200)	1450(1200)	1450(1200)
AUSTRALIA	Koolanooka	-	-	-	(500)	(550)	(600)	(650)	(700)	(700)	(700)	(700)

( ) Denotes Contracted

As of January, 1964

Thousand Metric Tons

Iron Ore Specifications and Trends

Recent Changes in Technology

In recent years, blast furnace operators have concentrated on improving the physical and chemical qualities of blast furnace burdens. The aim is to gain a higher productivity of blast furnaces and labour, a lower specific consumption of coke and other raw materials, and, hence, a lower overall cost of iron. Consequently, operators are placing more stringent limits on impurities in the ore, particularly phosphorus. Although these minor impurities may not present problems in pig iron production, excessive carry over into the steel making process is undesirable. Phosphorus, for instance, is not removed in the blast furnace and pig iron containing high phosphorus requires special treatment in conversion to steel which increases production costs.

In general, blast furnace operators are:

1. Demanding blast furnace feeds containing higher iron content and lower silica and alumina,

2. Demanding iron ores, concentrates or agglomerates low in impurities, particularly phosphorus,

3. Increasing the charge of structurally beneficiated feeds (agglomerates either sinter, pellets or nodules).

The previously mentioned increase in the iron content of the ore necessarily implies an increase in the iron content of the furnace burden. This in turn means that the amount of coke required per ton of pig iron will decrease and that the productivity of an individual blast furnace unit will be improved because less waste material is smelted in the blast furnace. One authority estimates that increasing the iron content of the burden from 50% - 55% increases the productivity of the blast furnace by 9% and reduces both coke consumption and overall processing costs (1).

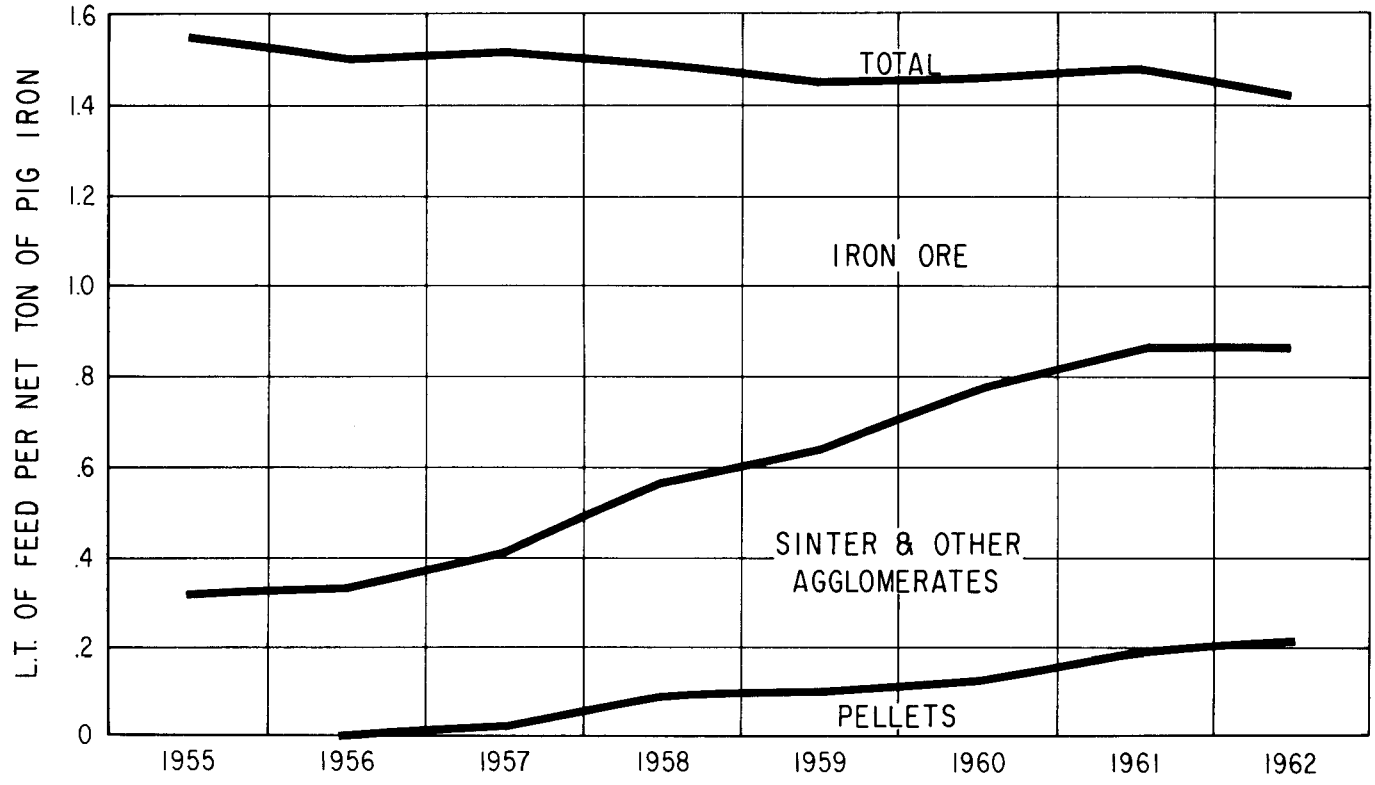
Perhaps the greatest single advance in blast furnace technology in recent years has been the general recognition that productivity can be materially improved by the use of correctly sized and agglomerated iron ore which permits more air to be blown through the tuyeres. Thus sinter or pellets used in a blast furnace materially increases its rated capacity. One report quotes an increase from 653 to 1140 tons of pig iron per day with the use of 100% sinter burden. In the United States, the use of 100% pellets has increased the pig iron production of one furnace from approximately 1800 tons per day to over 3000 tons per day(2).

The accompanying graphs illustrate the increased use of agglomerated burdens. The chart, Share of Sinter in Blast Furnace Burden, shows how quickly the use of agglomerated material increases after the initial period of slow growth. The United States is showing a marked increase in pellet consumption and Japan in sinter consumption. Judging from European experience with sinter, the rate of future increase is apt to be even greater.

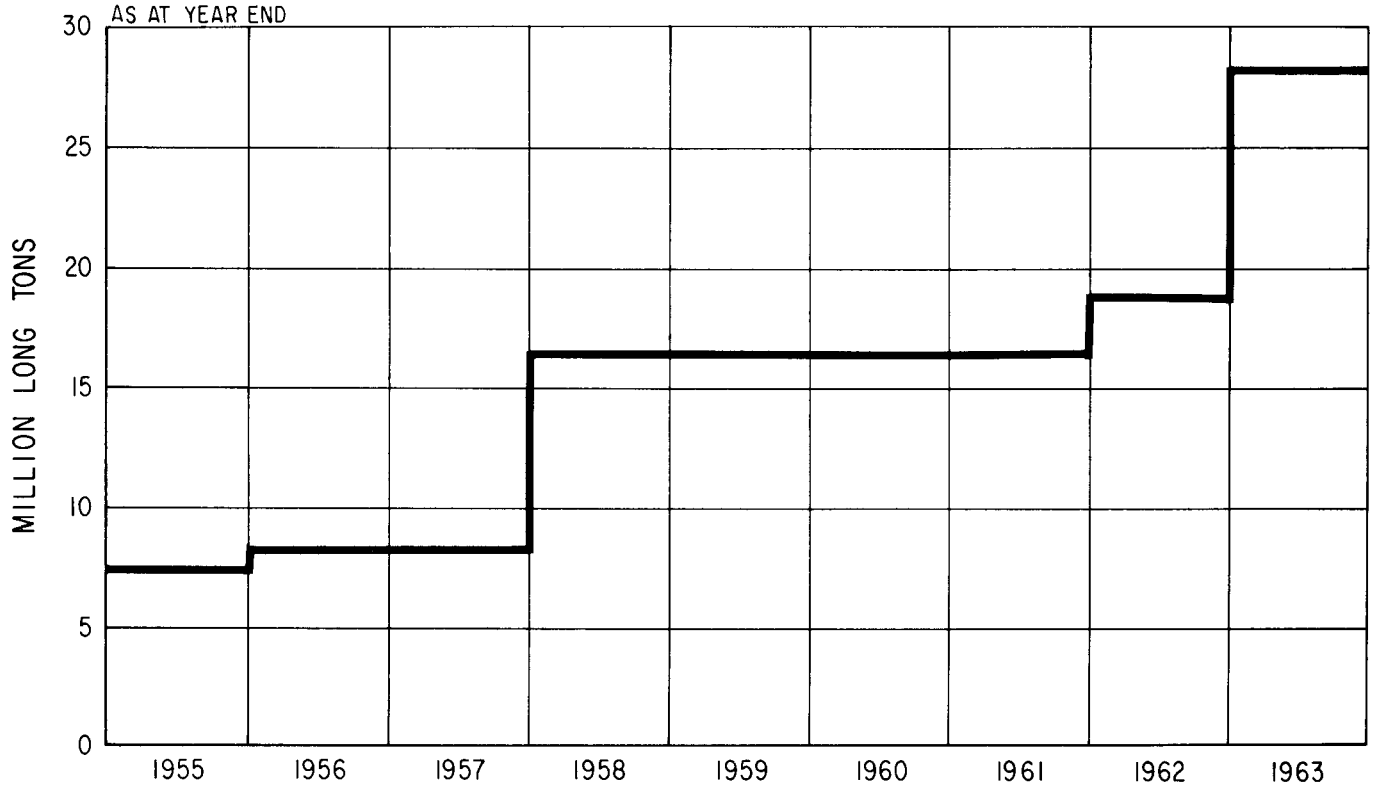
(1) Long-term Trends and Problems of the European Steel Industry - United Nations, 1959.
(2) The Agglomeration of Iron Ores and Concentrates - D. J. Hains, Canadian Mining and Metallurgical Bulletin, June, 1961.

UNITED STATES

CONSUMPTION OF IRON ORE AND AGGLOMERATES PER TON OF BLAST FURNACE PIG IRON

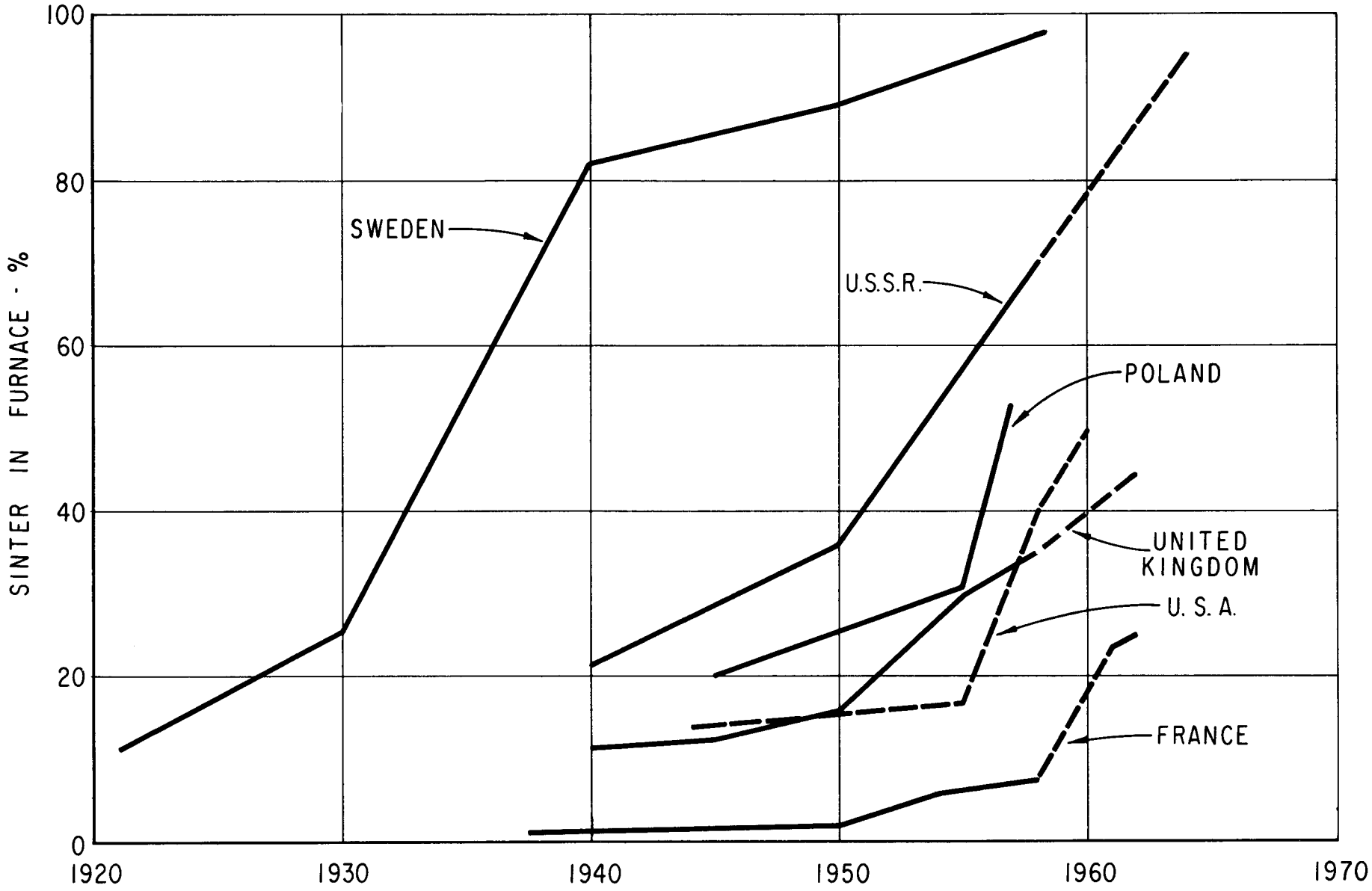


CAPACITY OF U. S. PELLET PLANTS



Source U.S. Bureau of Mines and American Iron and Steel Institute.

SHARE OF SINTER IN BLAST FURNACE BURDEN



Trends in the Japanese Industry

The change in the consist of blast furnace burdens throughout the world is also evident in Japan.

Quality of Ores

Although it is not possible to place definite specification limits on the quality of ore, concentrates and pellets which would be acceptable to the Japanese iron and steel industry, certain factors may be surmised from their current contracts and offers. It appears that the Japanese vary their specifications to fit three conditions:

1. Long term contracts are made only for premium products,
2. Annual purchases are made from mines with lower grades, and
3. Inferior ores may sometimes be taken in particular advantageous barter or trade agreements.

The following table outlines this thesis.

Japanese Imported Iron Ore Purchases

	1963(1)		1969	
	Thousand MT.	Fe%	Thousand MT.	Fe%
Lump				
Annual Purchases	6,492	60.9		
Contracted	11,939	62.4	14,500	64.2
Sub-total	18,431	61.9		
Sinter Feed				
Annual Purchases	2,775	58.0		
Contracted	4,127	60.8	3,200	62.3
Sub-total	6,902	59.7		
Pellets				
Annual Purchases	30	67.0		
Contracted	-	-	2,300(2)	65.2
Sub-total	30	67.0		
Total Purchases				
Annual Purchases	9,297	60.0		
Contracted	16,046	62.0	20,000	64.0
TOTAL	25,343	61.3	41,300(3)	

(1) Data is from contract summaries and there are minor differences in the actual purchase.

(2) Includes 800,000 MT. of Eagle Mtn. pellets not under contract when the contract summary shown on page H-34 was tabulated.

(3) Estimated requirements.

The following points should be noted in this table:

1. The difference in iron grade between contracted and annually purchased imported ore,

2. The improvement in the grade of contracted ore in 1969.

3. The emergence of pellet contracts.

The chart, Specifications for Japanese Imported Iron Ore, Comparison 1959 and 1963 Contracts, shown on page H-41, also illustrates changes taking place in the quality of ore being purchased.

Crest's product will have to be a sinter feed, pellet feed or pellet because of the character of the ore. From the foregoing data, it appears that the following iron grades would have to be met in order to secure a long term contract.

Sinter Feed	minimum	63%
Pellets	minimum	65%

For this high level of iron content, the maximum combined silica and alumina contents can only be 10 and 7 percent respectively so these specifications would not pose a problem. The sinter feed grade is perhaps higher than the previous table would suggest. However, Japan has several new offers of 64% Fe with deliveries commencing in 1965 and 1966. For this reason even the 1969 contracted quality may not be indicative.

The maximum permissable phosphorus content is not clearly defined. The Japanese have informed us that 0.07% is the maximum acceptable and this limit was also quoted to Australian producers. However, the large Indian lump contracts were negotiated at 0.10% P. and probably a good general rule for phosphorus content is:

- 0.10% P. acceptable
- 0.07% P. preferable

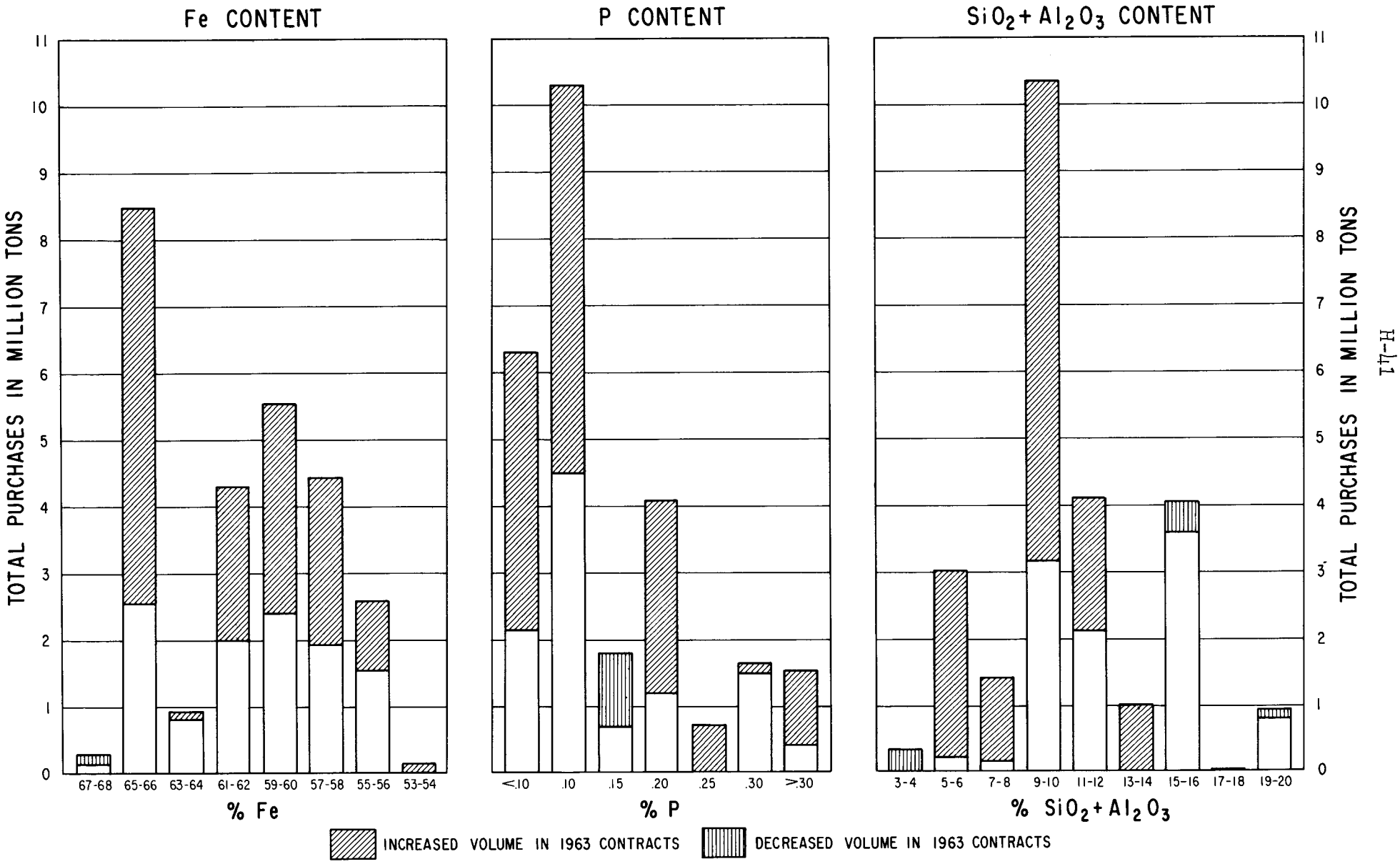
In setting these limits, only large volume long term contracts are being considered. It is likely that these specifications would be relaxed if volumes are small or the term of a contract is short. It might also be possible to contract ore not meeting these specifications on a discounted price basis but it is doubtful whether such a contract could be negotiated for any appreciable length of term.

Sinter Feed

As in other countries, there has been a marked trend in Japan towards the use of structurally beneficiated feeds, particularly sinter.

SPECIFICATIONS FOR JAPANESE IMPORTED IRON ORE

COMPARISON 1959 AND 1963 CONTRACTS



H-41

Japanese Sinter Consumption

	Sinter Consumption % B.F. Feed	Sinter Consumption* Million M.T.	Imported Ore in Sinter Million M.T.
1953	31.4	N.A.	0.2
1954	40.8	2.9	0.5
1955	44.4	3.5	0.8
1956	41.7	3.9	1.1
1957	43.9	4.5	1.5
1958	51.8	5.8	2.1
1959	48.0	6.8	3.1
1960	46.0	8.2	4.0
1961	54.0	13.3	8.0
1962	61.8	17.4	11.2
1963	N.A.	20.1	13.8

* Includes a small volume of pellets

Although there are no statistics available on the growth of Japanese sinter capacity, it is obvious from the consumption data that the majority of this capacity has been constructed in the last few years. Therefore, the Japanese steel industry will continue to utilize this capacity and import sinter feeds.

Japanese statistics for 1963 reveal the following feed to sinter facilities:

		Million M.T.
Domestic:	Ore	1.1
	Iron Sand	1.0
	Pyrite Sinter	1.9
	Other	1.8
	Sub-total	5.8
Imported:	Ore	13.8
	Total	19.6

However, in reviewing Japanese contracts for iron ore we find that only 6.9 million M.T. of "sinter feed" were imported or only 50% of the quantity actually consumed. The remainder of the sinter feed comes from the screening of ore classified as lump, for which contract specifications frequently allow a high portion of sinter feed size material (up to 30%).

Pellets

In recent years the Japanese have experimented with pellets. Kawasaki Steel Corp., in particular, has been producing pellets for a number of years, with 1962 production reported to be in excess of 1 million metric tons. In 1963 further interest in pellets was evinced when the Japanese steel industry imported a 30,000 M.T. trial shipment of Marcona pellets. It now appears that the Japanese pattern will follow that of the United States, with blast furnace

feed showing an increasing proportion of pellets. Current contract negotiations confirm this contention. In recent months the Japanese have signed or are in the final process of negotiating the following pellet contracts:

U.S.	Eagle Mtn.	18,000,000	over 10 yrs. commencing 1966
Goa	Chowgule	6,000,000	over 5 yrs. commencing 1966
Peru	Marcona	4,000,000	over 5 yrs. commencing 1964
Philippines	Larap	750,000 t.p.a.	not determined, commencing 1966.

If all contracts are finalized, pellet receipts in 1968 will be 4 million tons. There are also two large pellet offers from Australia which a Japanese team was sent to investigate in June of 1964. These are Pickands Mather's Savage River offer of 2 million tons annually and Cleveland-Cliff's Robe River offer of 3 million tons annually. A recent report indicates that Hamersley is also considering pellet production.

Reduced Iron Feeds

Although reduced or partially reduced iron feeds are not extensively used any where in the world, much study is being devoted to their development. In the future, there is the possibility that the Japanese could be interested in a feed for producing either iron or steel from which most of the oxygen has been removed prior to import. There appear to be several economic advantages to using this type of material, particularly to the Japanese steel industry which is dependent on imported raw material that travels longer distances than the raw material of other large steel producing countries.

World Trade in Iron Ore 1962

Country	Average Haul in Miles
Japan	5,600
United Kingdom	2,500
European Coal & Steel Community	3,000
United States	2,300

As the iron content of the raw material increases, the average cost per unit of iron decreases. Moreover, Japan also imports coking coal, about 60% of the 15.7 million M.T. used by the steel industry in 1962. Therefore, the importation of a reduced or partially reduced iron feed would not only provide a transportation savings on the iron but also a savings on imported energy.

The Japanese are currently negotiating a contract to purchase 250,000 tons per annum of "H-Iron". This process converts 65% iron fines to 90% iron using natural gas. The plan for this development involves the shipment of either Swaziland or Goan fines to Kuwait where, with cheap natural gas, a 90% iron product will be produced and then shipped to Japan. At present the "H-Iron" product is used as a substitute for scrap by the consumers. However, in the future, there is the possibility that feeds of this nature could partially replace iron ore.

Iron Ore Prices in Japan

Normal Contracts

In Japan there is no generally accepted schedule of prices to set the approximate rates on imported iron ore. However, ores which are under long term, large volume, contracts are often taken as a basis for comparison in negotiating prices. Generally, prices are determined by several circumstances, but particularly by the competition for sales, influenced to some degree by international trade objectives.

Iron ore prices are quoted in cents per 1% of iron content contained in either one metric or one long ton (1) of dry ore. Prices are normally stated in U.S. dollars or English pounds on either a loaded basis (F.O.B.) or a delivered basis (C.I.F.). The delivered basis is the only one of consequence since comparisons must be made at a common point. An example of a price calculation of ore delivered to Japan is as follows:

Texada Mines Limited
U.S. Dollars

	WLT*	DMT**
Contract Price F.O.B. 62% Fe		$ 9.45
Ocean Freight ***	$ 4.85	
Freight adjust. for 7% moisture and conversion to MT.		$ 5.11
Price C.I.F. Japan		$14.56
C.I.F. cents per iron unit		23.5¢

* Wet long ton
** Dry metric ton
***Normally delivery is computed to a single point, in Japan this is Yawata

Generally, contracts are negotiated on an F.O.B. basis with the Japanese being responsible for the shipping, although there are a number of C.I.F. contracts. There are also contracts with a division between C.I.F. and F.O.B., for example, the new Chowgule Goan pellet contract is being negotiated on this basis.

Contracts are written around the average grades anticipated from the iron mine and contain bonus and penalty clauses for deviation from this norm. Minimum acceptable grades are also set. The following was extracted from a contract with International Iron Mines in British Columbia which was negotiated in 1958 or 1959. It shows the method used to adjust the basic contract price for variations in specifications.

(1) 1 metric ton = 2205 lbs. 1 long ton = 2240 lbs.

Chemical Analysis	Standard Dry Basis	Guarantee Dry Basis	Penalties/Bonus
Fe	60%	58%	± 1% ± 30¢
SiO_2	12%	15%	+1% to max. of 15% -5¢/1%
S	1.50%	2.00%	+0.05% to max. of 2% -15¢/.05%
P	0.10%	0.20%	+0.05% to max. of 0.20% -8¢/.05%
Cu		0.05%	guaranteed less than
TiO_2		0.25%	guaranteed less than
Other Metals (except Mn. Mg. and Ca.)		0.15%	guaranteed less than
Moisture	5% at 105°C.		additional freight
Size	100% -¼"; 30% maximum -100 mesh guaranteed		

The standard dry basis is the norm on which the price is set and from which penalties are charged. The guarantee base is the limit of acceptance. In the event that any shipment does not meet the guaranteed specifications the buyer may either reject the shipment or accept it at a price negotiated with the seller.

It is not suggested that the specifications or penalties in this contract are standard in Japan. This example is only an illustration. Other contracts have different provisions:

1. Bonuses for 1% increase in Fe are as much as 40¢ with a similar penalty, others have a bonus of 20¢ and a penalty of 30¢.

2. Some phosphorus penalties are 10¢ per 0.05% increase but others are as high as 15¢.

As indicated earlier, there is no definite schedule for setting prices.

Japanese Prices

Prior to commencing a discussion of present and future prices for iron ore in Japan, the products which are to be discussed should be defined. These are:

(a) Lump Ore

Lump ore is ordinary blast furnace ore, normally sizes 60-80% between 10 mm. (3/8") and 200 mm. (8") with a maximum size of 250 mm. (10").

(b) Sinter Feed

Usually 60% to 70% of the material is between 10 and 100 mesh with the minimum size 250 mesh and the maximum 3/8". Sinter feed is usually priced at 2.5¢ per iron unit less than lump ore.

(c) Pellet Feed

The anticipated size is 80% minus 200 mesh. Very little pellet feed has been purchased by the Japanese but the price is expected to be 1¢ per iron unit less than sinter feed.

(d) Pellets

These are iron ore fines which have been agglomerated and heat treated to form a hard, permeable, uniformly sized blast furnace feed. Prices are expected to be 4 to 5¢ per iron unit higher than lump ore of the same grade.

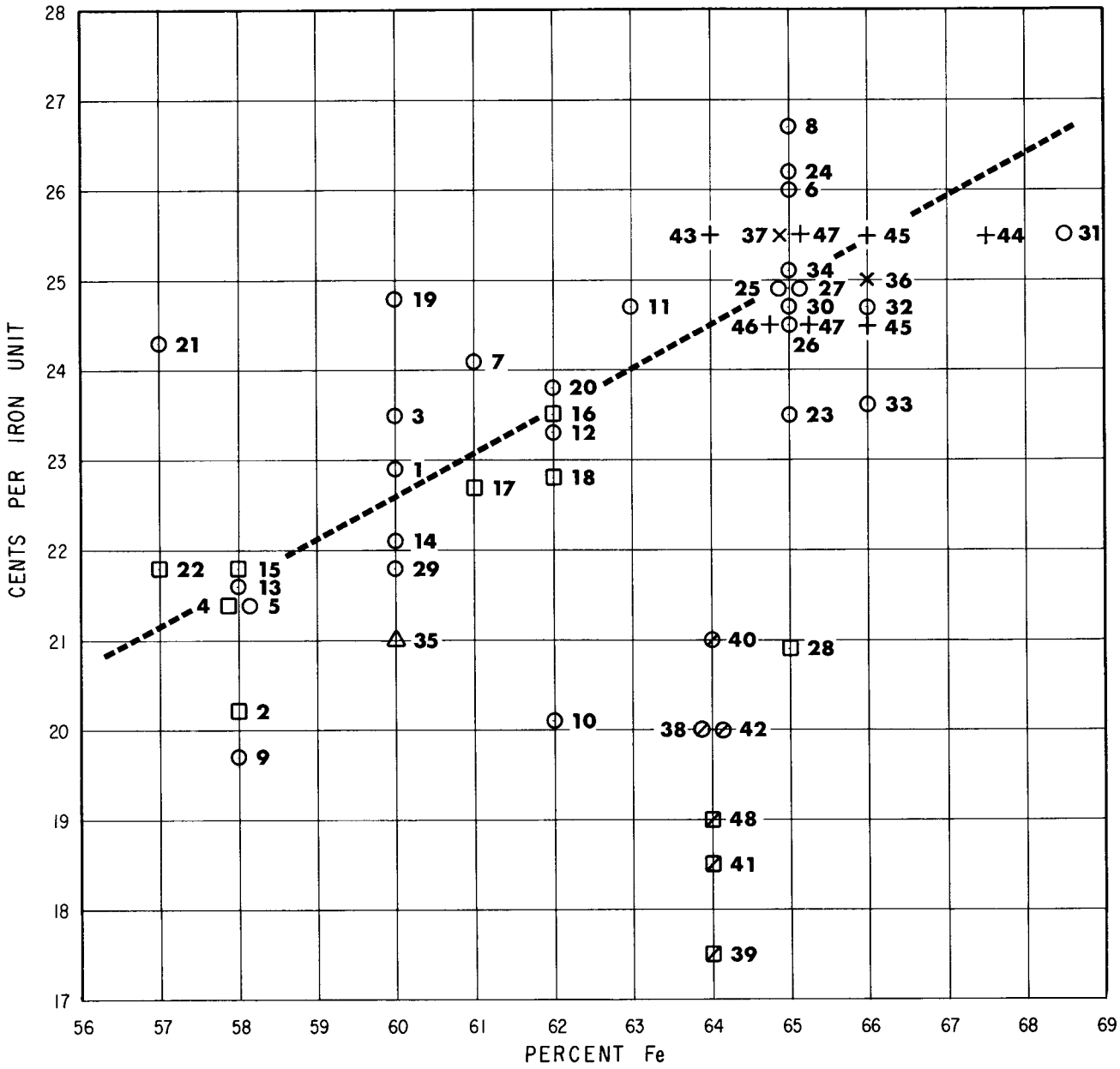
The chart, Japan - C.I.F. Price Per Metric Unit of Imported Iron Ore, on page H-47 plots iron ore prices against iron content and differentiates between lump ore, sinter feeds and pellets. Only contracts longer than one year and recent offers are included in this graph. The differences between old contracts, new contracts and offers is significant. Recent lump ore offers are at 20 and 21¢ per iron unit for a 64% product although the price in old contracts was 24.5¢ per iron unit. Pellets have been either contracted or offered at the old lump prices rather than at the normal differential of 4 to 5¢ higher. These comparisons illustrate the deterioration of prices in Japanese iron ore market within the past year.

On the chart, old contract sinter feed prices are somewhat interspersed with lump prices although a general discount is present. The differential of 2.5¢ per iron unit is more evident in the new offers, particularly those from Hamersley and Goldsworthy.

The weakening of ore prices, which is world wide, is a consequence of oversupply and reduced ocean shipping rates. On a 4,000 mile haul to Japan, a 50,000 DWT ore carrier will transport ore for approximately $1.00 per ton less than a liberty size carrier. In a buyers market, producers do not benefit from this savings and the C.I.F. price falls accordingly. The effect of lower shipping rates is reflected in the contracts now being negotiated which provide for delivery in super ore carriers. Future changes in freight rate should not reduce the C.I.F. price.

The other factor affecting price is the keen competition between the numerous suppliers vying for a share of the Japanese market. The Australian negotiations now underway will establish the future price level for some time to come. Two recently negotiated pellet contracts may suggest what this level will be. The prices in the seven-year pellet contract with Marcona are 26.5¢ per unit for 1964 and 1965 and 24.5¢ per unit for the following five years. The price falls to 24.5¢ per unit at about the time Australian companies could start production.

JAPAN - C.I.F. PRICE PER METRIC UNIT OF IMPORTED IRON ORE



OLD CONTRACTS

1	MALAYA	DUNGUN
2	MALAYA	DUNGUN
3	MALAYA	ROMPIN
4	MALAYA	ROMPIN
5	MALAYA	PONTIAN
6	INDIA	MEDIUM
7	INDIA	LOW
8	INDIA	HIGH
9	GOA	CHOWGULE
10	GOA	CHOWGULE
11	GOA	KANTILAL
12	GOA	KANTILAL
13	GOA	KANTILAL
14	GOA	KANTILAL
15	GOA	KANTILAL
16	CANADA	TEXADA
17	CANADA	LAKE KENNEDY
18	CANADA	JEDWAY
19	U.S.A.	O.C. NEVADA
20	U.S.A.	WABUSKA
21	U.S.A.	EAGLE MTN.
22	U.S.A.	EAGLE MTN.
23	CHILE	ALGARROBO
24	CHILE	ADRIANITAS
25	CHILE	SANTE FE
26	CHILE	COMINEX
27	CHILE	PHILBRO
28	PERU	MARCONA
29	PERU	MARCONA
30	PERU	ACARI
31	BRAZIL	RIO DOCE
32	BRAZIL	RIO DOCE
33	BRAZIL	RIO DOCE
34	AFRICA	BOMVU RIOGE

○ LUMP □ SINTER

NEW CONTRACTS

35	AUSTRALIA	KOOLANOOKA
36	GOA	CHOWGULE
37	U.S.A.	KAISER

△ LUMP × PELLET

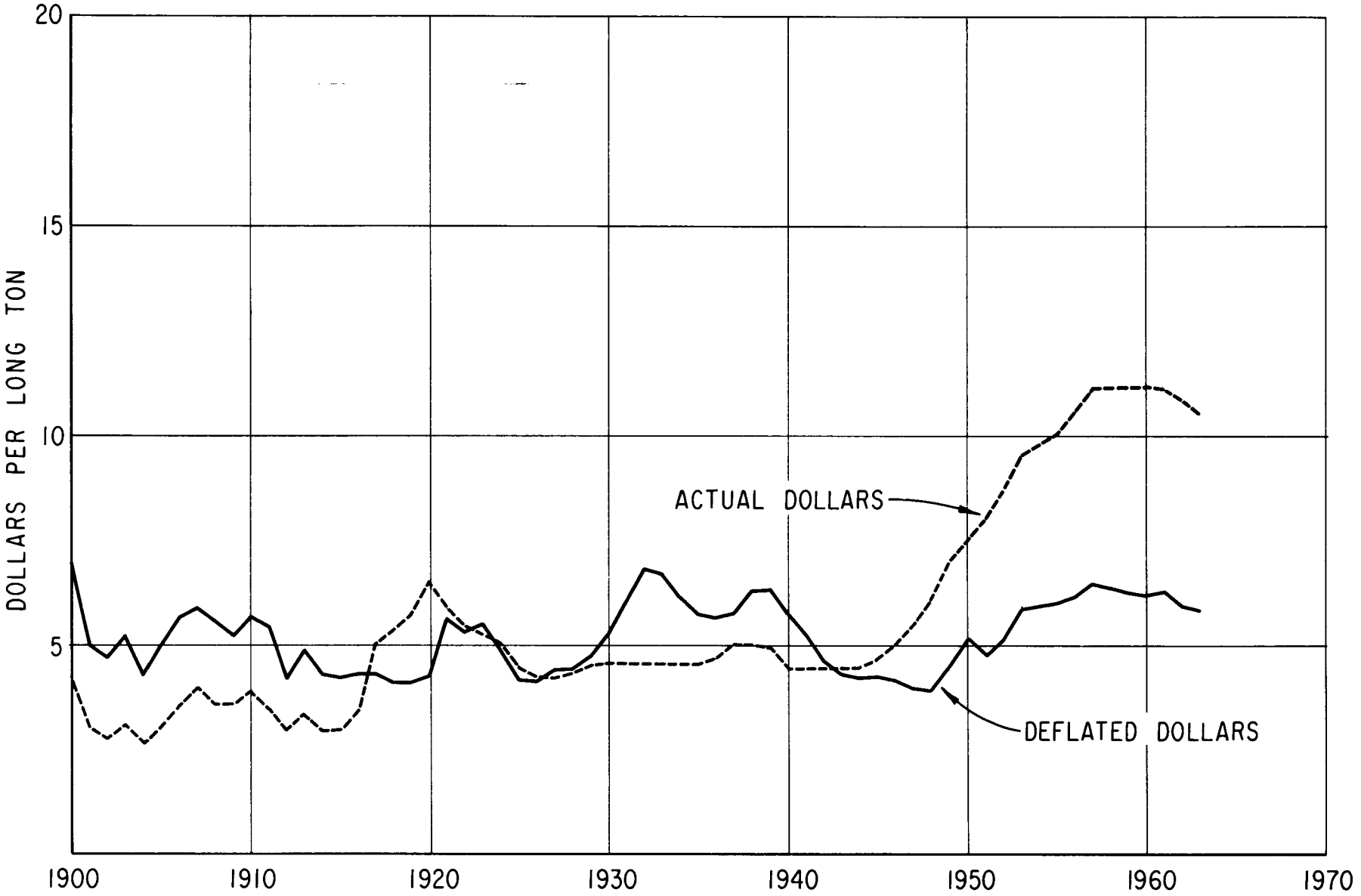
OFFERS

38	AUSTRALIA	HAMERSLEY
39	AUSTRALIA	HAMERSLEY
40	AUSTRALIA	GOLDSWORTHY
41	AUSTRALIA	GOLDSWORTHY
42	AUSTRALIA	MT. NEWMAN
43	AUSTRALIA	ROBE RIVER
44	AUSTRALIA	SAVAGE RIVER
45	PERU	MARCONA
46	U.S.A.	EAGLE MTN.
47	U.S.A.	DAYTON
48	CANADA	TASSOO

⊘ LUMP ⊠ SINTER + PELLET

MARCH 20, 1964

U. S. IRON ORE PRICE TRENDS



A ten year pellet contract with Kaiser for one million tons per year at 25.5¢ starting in 1966 was increased by 800,000 tons per year at 24.5¢, that is 1¢ per unit lower than the initial contract. The foregoing suggests that the Japanese have established their new price levels. For a 64% to 65% iron product, future prices (per iron unit) are expected to be: 24.5¢ for pellets; 20¢ for lump ore; 17.5¢ for sinter feeds and 16.5¢ for pellet feeds. Barring political disturbances, a buyers market will continue to exist and it is unlikely that any substantial real price increase will occur in the next decade. The graph, U.S. Iron Ore Price Trends, on page H-48, which shows both actual and deflated prices, displays an obvious relationship between inflation and iron ore prices. This will be reflected in future Japanese prices. However, the Japanese may be able to use the oversupply to reduce inflationary price increases to a minimum.

Japanese Investment and Purchase Policy

In studying the supply sources of ore, it was found that the Japanese had provided financial assistance for the development of a number of iron mines. A study was undertaken to investigate the scope of this investment for a dual purpose, that of ascertaining the possibilities of Japanese investment in the Crest project, and the effect of Japanese investment on contract negotiations.

The objectives of Japanese assistance have been twofold: to develop assured supplies of raw material and to promote exports. In fact it is quite unlikely that the Japanese steel industry would enter into any long term purchase contracts with a new mine unless much of the construction materials and equipment required to bring the mine into production were purchased in Japan. For such purchases, the Japanese steel companies are willing to provide assistance. Although the normal form has been short term credit grants, direct financial participation is also found and there is no reason to believe that under the proper economic incentives the Japanese industry could not be enticed into purchasing a share interest in a large iron mine.

The results of our study which embraced financial participation in minerals other than iron ore are:

1. Japanese steel companies have provided assistance to many of their iron ore suppliers. However, this has normally been done indirectly by guaranteed purchase contracts which provide incentive for trading companies and mining companies to advance funds, credits and technical assistance.

2. Direct proprietory participation by such Japanese firms in overseas iron mines is not as common as assistance given through credit grants for purchase of machinery and equipment in Japan. The credit grant system has the advantage of aiding foreign mines without loss in foreign exchange and, at the same time, promoting exports. Repayment of credit grants usually takes the form of a rebate on the price of ore imported over a period of up to 5 years.

3. Nevertheless, Japanese proprietory investment in minerals is found in many countries. In iron ore it is more common in Malaya, probably on account of the proximity of the two countries and of the economic conditions in Malaya. Also the large number of relatively small suppliers in Malaya has provided more opportunity to participate.

4. Usually, the Japanese have been willing to own less than the controlling share of foreign enterprises established for mineral exploration.

5. Japanese investments in foreign minerals have been relatively small, with the notable exception of the investment in Middle East oil, which was reported at $118 million in 1962 and the credit of $21 million granted India for the development of Bailadila iron ore.

The following material substantiates these conclusions:

1. Summary table of Japanese Foreign Investment in Iron Ore.

2. Details of Japanese Investment in Foreign Iron Mines.

3. Examples of Japanese Foreign Investment in Other Minerals:

   (a) Middle East Oil
   (b) Australian Coal
   (c) Copper concentrates

SUMMARY TABLE
JAPANESE FOREIGN INVESTMENT IN IRON ORE

Mine	Owner	Japanese Assn.	Type of Assistance	Details	Imports in 1962 Metric Tons	Imports in 1962 % of Total Imports
PHILIPPINES						
Larap	Philippines Iron Mines	Kinoshita	Development Loans	$3.2 million between 1952-61. Repayment out of ore. Guaranteed by Mills.	843,000	3.8
Sibuguey	Samar Mining Co.	Mitsui	Mine Survey	$0.3 million in 1957:Yawata, Fuji, N.K.K. backed loan.	400,000	1.8
Pioneer	Surigao Cons. Mining Property	Under negotiation C.Itoh & Kawasaki	Mining machinery & operating capital	Surveyed and recommended that $4.0 million be advanced to bring mine into production. No official confirmation on mine development		
MALAYA						
Dungun) Rompin)	Eastern Mining & Metals Co.Ltd. (EMMCO)			Canadian Trade Commissioner in Singapore reports that he believes development loans have been received. No direct ownership	2,881,000 883,000	13.0 4.0
Temangen	Oriental Mining Co.	Kokan Mining (N.K.K.)	Equity & Loan	$490,000 shares, 49% and $3,200,000 equipment in 1956. 1960 an additional $800,000. Repayment of loans out of production	488,000	2.2
Sri Medan	Malayan Miners Co. Ltd.	Japan Mining Co.	Technical Asst.		298,000	1.3
IMC Ipoh	Ipoh Mining Co.	Gosho	Technical Asst.		109,000	0.5

SUMMARY TABLE
JAPANESE FOREIGN INVESTMENT IN IRON ORE

Mine	Owner	Japanese Assn.	Type of Assistance	Details	Imports in 1962 Metric Tons	Imports in 1962 % of Total Imports
MALAYA (Cont'd.)						
Wardieburn	Bunga Raya Iron Mining Co. (BRIMCO)	Tokyo Tsusho and Kokan Mining (N.K.K.)	Equity & Loan	Paid up capital $300,000: Tokyo Tsusho 14%, Kokan Mining 25%. $250,000 loan guaranteed by 3 yr. purchase by N.K.K. on discount price.	60,000	0.3
Lumut	Federal Mining Co.(FEMCO)	Marubeni Iida Co.	Equity & Credit	Marubeni 49% of equity costing $98,000 and $260,000 credit.	311,000	1.4
Pontian	Pontian Iron Mining Co.	Iwai Trading & Japan Mining	Equity & Credit	Equity investment $49,000 and $670,000 credit arranged.	110,000	0.5
Endau	Endau Iron Mining Co.	Gosho-Nippon Mining	Investment & Technical Asst.	Japanese steel mills guaranteed purchase of ore.	109,000	0.5
HONG KONG						
Ma-on-shan	Mutual Trust Co.	Nittetsu Mining Co.	Loan & Technical Asst.	1953 equipment worth $580,000: 1959- $60,000: 59 technicians have assisted	111,000	0.5
GOA						
Chowgule	Chowgule & Co.	Kokan Mining	Equipment Credit	1951, 1st overseas investment of Japanese capital after the war -$1,620,000. 1959, mechanization of port $1,740,000. Backed by Big 3 Mills.	709,000	3.2
Shantilal Khantilal				Reported Japanese capital helped modernize this mine.	1,059,000	4.8

SUMMARY TABLE
JAPANESE FOREIGN INVESTMENT IN IRON ORE

Mine	Owner	Japanese Assn.	Type of Assistance	Details	Imports in 1962 Metric Tons	Imports in 1962 % of Total Imports
CANADA						
Zeballos	International Iron Mines Ltd.	Kinoshita	Development Loan	$1,750,000 was loaned for development. Company is controlled by Takahashi.	309,000	1.4
Jedway	Grandby Mining Co.	Sumitomo	Development Loan	Advanced $500,000 in cash and $500,000 in machinery.	150,000	0.7
CHILE						
Los Andrianitas	Cia Minera Atacama	Mitsubishi	Ownership	Undertaken jointly by Mitsubishi Mining & Mitsubishi Trading. Original investment $8,050,000.	935,000	4.2
PERU						
Marcona	Utah Construction & Cypress Mining	Mitsui	Indirect	Credit purchase of Japanese ships to transport ore.	1,801,000	8.1
RHODESIA						
Beacon Tor	Mine de Chrome de Fer S.A.	Kobe Steel Works	Equity	Reported controlled by Kobe with investment of $1,700,000	100,000	0.4
INDIA						
Rourkella	State Trading Corp.	Japanese Govt.	Development Credit	Technical assistance and credit of $8,000,000, 2,000,000 MT/Y 1964 production	-	
Bailadila	State Trading Corp.	Japanese Govt.	Development Credit	$21,000,000 for equipment not available in India, 4,000,000 MT/Y 1966 production	-	

SUMMARY TABLE
JAPANESE FOREIGN INVESTMENT IN IRON ORE

Mine	Owner	Japanese Assn.	Type of Assistance	Details	Imports in 1962 Metric Tons	Imports in 1962 % of Total Imports
GUINEA						
Simandon	Consafrique	Steel Mills	Exploration funds	Steel mills to put up 5% of exploration capital with consortium of European banks. Cost to mills estimated at $100,000.		
	TOTAL				11,666,000	52.6

DETAILS OF JAPANESE INVESTMENT IN FOREIGN IRON MINES

PHILIPPINES — Imports 1962 - 1,307,000 Metric Tons

Larap — Philippines Iron Mines

1952 — $1,000,000 U.S. was loaned by 4 mills: Yawata, Fuji, N.K.K. and Sumitomo to purchase mining equipment in U.S.A., to be repaid on an installment basis out of each ton of ore exported.

1955 — $1,800,000 U.S. was loaned on the strength of a joint guarantee by Japanese steel mills to construct ore processing facilities. Installment repayment was to be made out of each ton of ore shipped.

1961 — $400,000 U.S. was loaned by Kinoshita and guaranteed by 8 Japanese steel mills. The money was used to replace obsolete shipping facilities with Japanese machinery. Payment will be made annually on exports until the end of 1964.

Shipments from this mine in 1962 were 843,000 M.T.

Sibuguey — Samar Mining Company

1957 — Reportedly Mitsui advanced $300,000 for survey of mine. Yawata, Fuji and N.K.K. backed the loan.

Shipments from this mine in 1962 were 400,000 M.T.

Pioneer — Surigao Consolidated Mining Property

Not in Production

Japanese steel mills and financiers have shown an interest in financing the Pioneer Iron Property. A team of engineers were sent by Japanese interests in 1961 and favourably recommended the operation of this property. A tentative financing agreement was signed in the latter part of 1961 with Japanese interests subject to the approval of the terms and conditions of the agreement by the Central Bank of the Philippines. The Central Bank approved the terms but to our knowledge the contract has not been finalized.

The financing agreement involves $4,000,000 in the form of mining machinery and cash required for operating capital.

It is reported that C. Itoh & Co. and the Kawasaki Steel Co. are the backers of the project.

MALAYA Imports 1962 - 6,530,000 M.T.

Temangen Iron Ore Mine

In 1956 a basic contract for developing a mine in the Federation of Malaya was signed between Boustead & Co. Ltd., a local firm of British capital and Kokan Mining Co., a Japanese Mining Co. Oriental Mining Co. was formed by joint investment on the strength of guarantees to purchase iron ore on long term basis by three major steel mills in Japan (Yawata Iron & Steel Co., Fuji Iron & Steel Co. and Nippon Kokan K.K.). Kokan Mining Co. is a subsidiary of N.K.K.

Authorized capital	:	Malayan $1,500,000
Paid up capital	:	Malayan $1,000,000
Boustead & Co. Ltd.		owns 51% of stocks; and
Kokan Mining Co.		owns 49% of stocks.

Kokan Mining Co. loaned approximately U.S. $3,300,000 to the company to supply the machinery and equipment necessary for developing the mine. The loan was to be reimbursed on an installment basis from each ton of iron ore exported over 5 years after the start of production. At a production rate of 350,000 tons annually, the aggregate quantity of iron ore to be shipped is expected to be 1,750,000 tons. Thus $1.88 U.S. has to be paid back from each ton of the iron ore shipped. A price reduction at this rate was made to repay the loan.

The operation was carried on successfully and the record of production is as follows:

1958	275,000 M/T exported
1959	385,000 M/T exported
1960	525,000 M/T exported
1961	607,000 M/T exported

Sri Medan — Malayan Miners Co. Ltd. (MMC)

Technical assistance was provided by the Japan Mining Company.

Shipments from this mine in 1962 were 298,000 M.T.

Ipoh — Ipoh Mining Company (IMC)

Gosho Trading Co. provided engineering to advise on technical problems.

Shipments from this mine in 1962 were 109,000 M.T.

Wardieburn Iron Mine — Bunga Raya Iron Mining Co. (BRIMCO)

The company was formed in April, 1961, with paid up capital of $300,000.

14% - Tokyo Tsusho Kaisha Ltd.
25% - Kokan Mining Co. (N.K.K.)
61% - Lim Choi Seng, president of Abdulla Ghaffar Mining Company and others

Wardieburn Iron Mine - Cont'd. Bunga Raya Iron Mining Co. (BRIMCO)

N.K.K. guaranteed to purchase 120,000 M.T. for 3 years and loaned $250,000 for the machinery and equipment necessary to develop the mine. Repayment is over 3 years with a reduction in the ore price of 76¢/M.T. or a total of $275,000. Shipments commenced in August, 1962.

Shipments fromthis mine in 1962 were 60,000 M.T.

Pontian — Pontian Iron Mining Co. Ltd.

Reportedly Pontian Tin Mines Ltd., Japan Mining and Iwai Trading Co. formed a new company to develop this mine. Equity investment was $49,000 and a credit of $670,000 was arranged.

Shipments from this mine in 1962 were 110,000 M.T.

Lumut (Ipoh Area) — Federal Mining Co. Ltd. (FEMCO)

This is a joint venture between the Perak Iron Mining Co. and the Japanese trading firm of Marubeni Iida Co. It is reported that Marubeni owns 49% and invested $98,000 in ownership and $260,000 in credit.

Shipments from this mine in 1962 were 311,000 M.T.

Endau — Endau Iron Mining Co.

Both the Gosho Trading Company and the Ipoh Mining Company have invested in this mine. Technical assistance was received from the Nippon Mining Company. Japanese steel mills have guaranteed purchase of ores produced.

Shipments from this mine in 1962 were 109,000 M.T.

HONG KONG — Imports 1962 - 122,000 M.T.

Ma-on-shan — Mutual Trust Co. Ltd.

In 1958 the Japanese firm of Nittetsu Mining Co. completed an agreement to loan Hong Kong's Mutual Trust Co. equipment worth $580,000 for a plant at their Ma-on-shan iron mine. In 1959 production dropped and Nittetsu supplied $60,000 worth of equipment for an additional plant. In addition, Nittetsu has so far sent 59 engineers and advisers to assist in production problems.

Shipments from this mine in 1962 were 111,000 M.T.

GOA — Imports 1962 - 2,412,000 M.T.

Chowgule — Chowgule & Co.

The first overseas investment of Japanese capital after World War II was made at this mine. In 1951 an agreement was signed for the development of Chowgule and Co. mines with Kokan Mining Co. supplying $1,620,000

Chowgule (Cont'd) — Chowgule & Co.

in the form of plant exports. Three major steel mills, Yawata, Fuji and N.K.K. backed the deal by backing Kokan for the necessary bank loan and by signing contracts to buy 4.5 million tons of iron ore which will enable the company to repay its debt to Kokan. In 1959, Kokan also supplied equipment worth $1.74 million for the mechanization of Chowgule's berth at Mormugao. This loan was again backed by the three steel mills. The loan is to be recovered from the price of 3 million tons of iron ore to be shipped to Japan over 4½ years.

The shipments of this mine in 1962 were 709,000 M.T.

Shantilal Khantilal

It is reported that Japanese capital was used to modernize this mine.

The shipments from this mine in 1962 were 1,059,000 M.T.

CANADA — Imports 1962 - 1,574,000 M.T.

Zeballos — International Iron Mines Ltd.

Kinoshita and Company supplied $1.75 million for the development of this mine. This will be repaid with iron ore. C. T. Takahashi holds the controlling interest in International Iron Mines Ltd.

Shipments from this mine in 1962 were 309,000 M.T.

Jedway — Jedway Iron Ltd. (Sub. Granby Mining Co.)

It is reported that Sumitomo advanced $500,000 in cash and $500,000 in machinery to the Granby Mining Company for this development.

Shipments from this mine in 1962 were 150,000 M.T.

UNITED STATES — Imports 1962 - 864,000 M.T.

Eagle Mountain — Kaiser

Mitsui and Co. Ltd. reported that a certain financial arrangement is under negotiation between the mine owners and a Japanese trading firm.

Shipments from this mine to Japan in 1962 were 421,000 M.T.

CHILE — Imports 1962 - 3,011,000 M.T.

Los Andrianitas — Cia Minera Atacama

This project was undertaken jointly by the Mitsubishi Mining Company and Mitsubishi Shoji Kaisha Ltd. Investment is reported at $8,050,000. Yawata endorsed the undertaking and agreed to purchase the iron ore.

Shipments from this mine in 1962 were 935,000 M.T.

PERU — Imports 1962 - 2,495,000 M.T.

Marcona — Marcona Mining Co. (Utah Construction & Cypress Mining)

There is no reported financial backing by the Japanese in the mining operation. However, as a by-product of the contracts negotiated by the Japanese, several large ore carriers have been constructed in Japanese shipyards to transport the ore. These ships have been built for San Juan Carriers, the transportation arm of Marcona. It is reported that these ships are built on credit with repayment being made over the term of the 7 year ore contracts.

N.K.K. contracted to take 420,000 t.p.a. from 1962 to 1969 and built a 65,500 DWT ship at a cost of $8,900,000.

Yawata and Fuji contracted to take 900,000 t.p.a. from 1963 to 1970 and Mitsui built two 67,500 DWT carriers.

N.K.K. and Sumitomo contracted to take 800,000 t.p.a. from 1964 to 1971 and N.K.K. is building two 67,500 DWT carriers.

Shipments to Japan from this mine in 1962 were 1,800,000 M.T.

INDIA — Imports 1962 - 2,092,000 M.T.

Rourkela — State Trading Corporation (Indian Govt.)

The Japanese government has granted India a credit of $8,000,000 to purchase Japanese machinery for the development of this mine and it is also providing technical assistance. Production is scheduled for 1964 and a ten year contract for 2,000,000 t.p.a. has been signed.

Total cost of the project is estimated at $50,000,000.

Bailadila — State Trading Corporation (Indian Govt.)

The Japanese government is to assist India in the purchase of machinery, equipment and incidental materials which are not available in India, to an extent of $21,000,000. Japanese financial assistance in the purchase of machinery and equipment will be repaid at the accumulated interest rate of 6% per annum. Repayment begins after the first shipment of iron ore from Bailadila to Japan and will be completed within 5 years. A contract scheduling deliveries in 1966 at 4,000,000 t.p.a. and extending for 15 years has been negotiated.

Total cost of the project is estimated at $162,000,000.

RHODESIA — Imports 1962 - 100,000 M.T.

Beacon Tor — Mine de Chrome de Fer S.A.

The property is controlled 80% by Kobe Steel Works and 20% by Continental Ore of N.Y. Kobe's investment in this mine is reported to be $1,700,000.

Shipments from this mine in 1962 were 100,000 M.T.

GUINEA

Simandon — Consafrique

A consortium of European banks have been granted exploration rights. Japanese steel companies have decided to participate in this venture and are contributing 5% of the exploration capital. This is estimated to be only $2,000,000 in total. European steel mills are also participating.

EXAMPLES OF JAPANESE FOREIGN INVESTMENT IN OTHER MINERALS

MIDDLE EAST OIL

Japan obtained concessions in the Offshore Neutral Zone which is owned jointly by Kuwait and Saudi Arabia. In 1957 the Japan Petroleum Trading Company obtained the Saudi Arabia portion and in 1958 the same company, under the name Arabia Oil Company, obtained the Kuwait portion. The concession agreements signed with these countries call for approximately 57% of the profits to be paid to the government in taxes. In addition, the company had to agree to construct a refinery and petrochemical plant at certain levels of production. The governments have the right to participate up to 10% in the stock of the company.

The company is owned by diverse Japanese industrial concerns. The original risk capital for exploration, estimated at between $15 and $20 million, was provided by these private investors with a loan from the Japanese government of $7 million. In 1961, a new stock issue of $50 million was made, increasing the capitalization to $82 million. The concession countries purchased their 10% equity at this time.

The operation has been successful and, at the end of 1962, production capacity was reported at 173,000 B/D although production during the first half of 1962 only averaged 28,030 B/D. The company is now contemplating the refinery which it is obligated to build in Saudi Arabia under its concession terms. Investment to the end of 1962 is reported at 117.6 million dollars.

AUSTRALIAN COAL

Thiess - Peabody - Mitsui Coal Co. Pty. Ltd.

Mitsui and Co. of Japan have purchased a 20% share-holding in the $4,500,000 capital of the former Thiess - Peabody Co. Pty. Ltd. which is developing the Kianga - Moura coalfield. The state government's franchise requires the annual production of at least 500,000 tons of coal for export and the construction of a 120 mile railway from the field to Gladstone. The company has a $31 million order for 3,400,000 tons of coking coal over the next 7 years. Already $11 million has been spent on development and production will soon increase sharply. An increase in production to 2 million tons is planned.

Mitsui and Company invested $900,000 in equity and will also provide $1,400,000 loan for development expenditures.

COPPER CONCENTRATES

Philippines: Rapu-Rapu Mine

Much development work has been done since 1953 on Rapu-Rapu Island off the southeastern coast of Luzon as a joint project between Nippon Mining Company of Japan and Hixbar Gold Mining Company. A mill of 275 tons/day was built at the Rapu-Rapu Mine. Nippon Mining Co.

advanced $225,000 U.S. for the construction of the mill as a loan to be repaid through the sale of copper concentrates. During 1939-1941 shipments were made to Japan and during the war the Nippon Mining Company operated the mine. The mine was re-opened in 1950. To facilitate participation in this venture, Nippon Mining Company organized the Philippine - Nippon Mining Company early in 1958.

Philippines: Atlas Consolidated Mining & Development Corporation

In 1953 the Mitsubishi Metal Mining Co. invested $2,500,000 in Atlas Consolidated Mining & Development Corp., a subsidiary of the large Philippine concern, Soliano. Of this amount $1,110,000 was for machinery to develop mines on Cebu Island. The investment by the Japanese company is to be repaid in copper concentrates.

Philippines

A cooperative project between Mitsui Metal Mining Company, Nanyobusan Trading Co. of Japan and Marinduke Iron Mining Company was responsible for the development of two copper mines in the Philippines.

Canada: Bethlehem Copper Corporation

The final exploration and development of this copper mine was partly financed by the Japanese Sumitomo group of companies who invested $850,000 in equity and provided a $5,000,000 loan for development. The loan is secured by a 6% first mortgage bond issue.

Sumitomo also entered a contract to purchase all the concentrates produced by the mine for a ten year period.

The equity investment gives Sumitomo a 16% interest although options have been retained to increase this to a 28% share.

COMPETITOR NATIONS IN THE PACIFIC MARKET

Future Suppliers

Projections of Japanese iron ore supply indicate that Japn will reduce its dependency on the Far Eastern suppliers and that India will become the largest supplier. Theemergence of Australia as a prominent supplier is also evident. The anticipated changes are shown in the following table.

Iron Ore Imports

Area	1963 Fe Grade	1963 %	1970 %	Distance to Japan Miles
Far East	58.6	31.5	15.0	1,400 - 2,700
Indian & Goa	62.4	22.5	29.5	4,400 - 4,800
North America	60.0	13.5	14.0	4,200 - 4,700
South America	63.9	27.0	23.5	8,600 -12,500
Africa	64.8	3.7	5.4	7,400
Australia	-	-	12.6	3,700 - 5,000
Other	-	1.8	-	
Total	61.3	100.0	100.0	

Far East

Although the Far East is now the largest supplier of iron ore to Japan, the future for exports from this area is not bright.

The supply from Malaya, which represented 23% of the Japanese imports in 1963, originated in 14 mines, some of which are very small. The quality of the ore is not as good as that from other sources, reserves are being depleted and loading facilities are extremely poor. In many instances ships have to be anchored offshore and the ore moved along side in lighters and hand loaded.

The other large supplier in the Far East is the Philippines. Although the quality of the ore is below that of other areas, mines are modern and shipping facilities are good. Shipments from this area should increase slightly with old mines maintaining their position and one new mine, Pioneer, which is being developed with the assistance of Japanese capital, going into production in 1965.

The other minor suppliers, Hong Kong, Korea and Thailand, are only expected to maintain their present volume.

India

Even though India and Goa are now one political unit, the mechanics of iron ore production differ. In India, all iron ore mines are owned by the government and production and sales are controlled by the State Trading Corporation, whereas in Goa, the mines are privately owned.

India, having immense high grade ore reserves, is scheduled to become the largest supplier of iron ore to Japan. Although only 2.5 million tons were

exported to Japan in 1963, two cooperative projects of the Japanese and Indian governments are scheduled to increase shipments of ore by 6 million tons in 1967. Assuming that current purchases are continued, exports from India to Japan will be 8.5 million tons in that year.

It is difficult to assess the competitive position of Indian iron ore in relation to other suppliers since the objectives of a state-owned enterprise are not the same as those of private enterprise. For instance, great emphasis has been placed on these projects as a means of obtaining foreign exchange. Projects of this nature also increase employment and develop new railroads and port facilities which hasten the economic and industrial development of underdeveloped nations. These are factors which cannot be reckoned in a strictly economic sense when comparing costs.

The following outlines both the Rourkela and Bailadila projects in some detail.

Rourkela Area

In October, 1955, at the Colombo Plan Conference held in Singapore, representatives of the Indian government suggested a plan for development of iron ore production with Japan as the potential purchaser and the United States as the financial backer. At this time the Pacific basin was believed to be iron deficient, Japanese ore requirements were increasing rapidly and assured supplies of high grade ore were extremely desirable.

The major points of this plan were:

1. The Barsua mine in the Rourkela area of Orissa State, which was developed to supply iron ore to the iron and steel plant at the Hindustan Steel Corporation in Rourkela, had a surplus production capacity of high-grade iron ore (iron content of 65 percent and up).

2. From the surplus ore produced, 2,000,000 tons per year, initially, would be furnished to Japan.

3. For this export a new railroad would be constructed between the mine and the port of Vizagapatnam.

4. Total capital required for this project would be $50,000,000 of which the Indian government would furnish $17,000,000 (in rupees). Some $8,000,000 would be supplied by Japan, mainly in the form of locomotives for the railroad. The balance of $25,000,000 was expected to come from the Presidential Development Fund in the United States.

To consider these proposals Japanese iron and steel, mining and trading groups sent a preliminary survey mission to India in August, 1957. The aims of this mission were twofold:

1. To survey the details of the pertinent mines, railroads, ports and port facilities, and

2. To investigate the possibility of available, alternate iron ore deposits located closer to transportation facilities.

The fact that the Barsua mine is located 450 miles from the port of Vizagapatnam with consequent high-cost inland transportation, prompted this latter aim. From information gathered and correlated by this preliminary survey mission, Japan offered to cooperate in the development of India's iron ore resources but made alternate proposals to decrease the transportation problem. After negotiations between the Indian government and a preliminary mission headed by Mr. M. Watanabe and representing Japanese iron and steel groups, the counter proposals were accepted by the Indian government.

Subsequently, in December 1957, a second survey mission of 51 members headed by Mr. T. Asada and including mining, railroad and port experts, was sent to India. This survey mission finished its investigation in February, 1958. As a result of this second survey, a general agreement with the Indian government was signed on March 19th, 1958. The agreement gave Japan priority in the development of iron ore mines in the Rourkela area. It also gave Japan a guarantee of 2,000,000 tons of ore annually after completion of the development project. The first shipment of 2,000,000 tons of ore was expected to commence in 1964.

Development of Rourkela has fallen behind schedule because of delays in port construction at Vizagapatnam. However, partial deliveries are expected to commence in June of 1964, with 350,000 M.T. being delivered during the remainder of the year. The grade of the ore will average 64% iron. The contract price for 1964 is to be 22.8¢ per iron unit, with subsequent prices to be negotiated annually.

Bailadila Area

The Asada mission which finalized the agreement on Rourkela concluded that the Bailadila area was actually a better development prospect than Rourkela because of its location nearer to the sea and its higher quality ore. According to the Asada report, the Bailadila area contains more than 700,000,000 tons of high-grade ore with an average iron content of 65%. Moreover, rail distance to the port of Vizagapatnam would be less than 300 miles from any point in the district, whereas the distance from the Kiriburu mines of the Rourkela district is over 460 miles.

When final agreement on development of iron ore deposits in the Rourkela area was reached on March 19, 1958, the Indian Iron Ore Negotiating Committee and the Japan Steel Mission took into account the stipulation that ...."Japan shall gradually increase her quantity of ore to be purchased and India shall meet her requirements provided conditions then prevailing permit the purchase and supply. For meeting Japan's growing requirements India shall develop iron ore mines in the Bailadila and Sukinda areas..." Moreover, in order to meet future increased demand for iron ore in Japan, India promised priority to Japan in the development of iron ore deposits in the Bailadila area. The recommendation of the Asada mission brought about further negotiations and in March, 1959, yet another mission was sent to India. This mission was headed by Mr. S. Nagano. These discussions centred around the development of the Bailadila area.

The Nagano mission submitted its proposals through the Indian Ministry of Commerce and Industry concerning the development of the Bailadila area. Major points of this proposal were as follows:

1. India was to make a preliminary study regarding the potential development of the Bailadila area. Following this study, the two nations would hold special discussions concerning mine development, railroad construction, and the building of port facilities, provided the Indian government would permit Japanese iron and steel company personnel to help in the research work.

2. The two nations working together were to develop the mine in the Bailadila and Rourkela area. And, after 1966, Japan was to accept 6,000,000 tons of ore per year to be shipped from the port of Vizagapatnam.

3. Details regarding development of the Rourkela deposits would be decided after a more complete exploration was made.

4. It was hoped that necessary capital could be secured through Japanese loans and from the Presidential Development Fund in the United States. The development program was to be an integral part of the Five Year Development Plan of the Indian government.

Memoranda were exchanged and the Indian government agreed to study further the possibilities of developing the Bailadila area. By January, 1960, the Indian government had drawn up a plan of development. These plans were presented to the Japanese iron and steel groups as a basis for discussions leading to final agreement.

1. The project involves:

   (a) the production of iron ore at Bailadila,
   (b) construction of a railroad line from the Bailadila area to the port of Vizagapatnam.
   (c) adequate loading facilities at Vizagapatnam.

2. Capital requirements for the project were estimated at over $162 million for railroad and mines.

   (a) The estimated construction cost of a new railway 309 miles long was $115 million with the cost of the necessary rolling stock set at a little over $20 million.

   (b) The capital for mining needs was estimated at $27 million. Foreign exchange requirements for the mining projects would be about $19 million.

3. For investment of the magnitude required for this project it was expected that the Indian government and other authorities concerned could be called to sanction and undertake the investment. India expected that the required foreign currency, roughly estimated at $21 million, would be available from Japan.

4. A six year period was considered to be adequate for the development program.

As a result of these memoranda the Japanese iron and steel groups again sent a mission to India headed by Mr. S. Nagano. A series of meetings

were held between March 1st and 8th, 1960, concerning the details of the project. Final agreement in the development of iron ore mines in Bailadila was reached on March 8, 1960. The memorandum signed by both Mr. S. Ranganathan, chairman of Indian Iron Ore Negotiating Committee and Mr. S. Nagano, leader of Japan Steel Mission, in New Delhi on March 8, 1960, stressed the mutual cooperation through which the agreement was reached.

> "...These discussions, as on the earlier occasion, stemmed from the friendly relationship and mutual trust existing between India and Japan and also took account of the mutual benefits accruing to the two countries, such as the installation and improvement of the mining industry in India and the continued availability of iron ore on a long-term basis and at fair reasonable prices to Japan."

The final agreement signed by the governments of India and Japan states that:

1. Japan shall purchase, and India shall supply on terms and conditions to be agreed upon between the two parties, approximately 4,000,000 tons of iron ore per annum from mines to be developed in the Bailadila area, on a long-term basis commencing from the middle of the year 1966, in addition to Japan's purchases of iron ore from Kiriburu mines and other sources in India under the agreement dated March 19, 1958.

2. Before the commencement of the first shipment of Iron ore from the Bailadila area, India will develop the mines, complete the construction of the railways between the mines and the port of Vizagapatnam, and mechanize facilities at the port suitably for loading this additional quantity.

3. The price of iron ore will be negotiated between India and Japan in a spirit of reasonableness, mutual trust and confidence.

4. For the implementation of this project:

   (a) India shall provide all the necessary funds for the purchase of machinery, equipment, other materials, and services available in India.

   (b) Japan shall assist India financially in the purchase of machinery, equipment, and incidental materials which are not available in India, to an extent equivalent to $21,000,000 (U.S.) according to terms and conditions to be agreed upon by the governments of India and Japan.

Also, in the addendum, the two parties agreed upon the following:

1. The iron ore will meet the following specifications:

Iron	(a)	65% basis below 63% rejection
	(b)	62% basis below 60% rejection

SiO_2 + $A1_2O_3$	12% maximum
Sulphur	0.15% maximum
Phosphorus	0.1 % maximum
Copper	0.05% maximum
Size	minimum $\frac{1}{2}$", maximum to be agreed upon
Free moisture	5% maximum

The proportion of the two grades of ore was to be determined as soon as the prospecting of the deposits is completed keeping in view Japan's requirement of high grade ore.

2. The price will be determined prior to the commencement of shipment each year by negotiation. Negotiation will consider:

   (a) the contracted purchase price of ores bought by Japan from other sources, and

   (b) the prices of India iron ore sold to countries other than Japan during the preceding 12 months.

3. The term of the first purchase contract is 15 years.

4. Japanese financial assistance in the purchase of machinery and equipment is to be repaid at the accumulated interest rate of 6 percent per annum. Such repayment will commence after the first shipment of iron ore from Bailadila to Japan and will be completed within 5 years.

The Indian government agreed to develop the port facilities at Vizagapatnam. A port improvement program was necessary in order to permit steady shipment of over 6,000,000 tons of iron ore annually when the Bailadila project went into production. The channel of the port was to be enlarged sufficiently to permit ore carriers of 32 foot draft and 600-foot overall length (25,000 ton carriers) to go through day and night. Additional development will be considered in the future to meet a demand for larger vessels. The port will have two berths, each 800 feet long and 40 feet deep. To ensure speedy loading, there will be:

1. an iron ore stock yard with a minimum capacity of 400,000 tons,

2. two reclaiming shovels, each with a rated capacity of 800 tons per hour,

3. a main reclaiming conveyor belt with a rated capacity of 2,000 tons per hour, and

4. two sets of loading towers, each with a rated capacity of 2,000 tons per hour.

Recent reports state that development of the Bailadila deposit is proving to be more costly than was originally estimated and India has requested an additional $21 million financial assistance as well as more technical assistance. It has also been reported that India suggested to Japan

that the 2 million tons of ore scheduled to come from Rourkela be transferred to Bailadila as the ore from Rourkela could now be used in the Indian iron and steel industry. No further information is available on these proposals.

Summary

Although it is difficult to assess the competitiveness of these mines, it would seem that these projects could stand stiff competition:

(a) The direct shipping reserves are large and the grade is excellent.

(b) Mining is reported to be easy and new mechanized mining methods are being employed.

(c) Although the railway transportation to port is 460 miles at Rourkela and 309 miles at Bailadila which is a long way compared to many other sources, it is over a government owned and operated railway.

(d) New port facilities capable of handling larger size carriers are being developed.

(e) Ocean distance to Japan is only 4,500 miles and compares favourably to most other sources.

(f) Government ownership of all facilities and the absence of taxes, royalties and profit incentives will permit price reductions to be made to meet competition.

Goa

Goa is a small area of 1,300 square miles located on the West Coast of India. Until 1961, Goa was a Portuguese territory but it is now controlled by India. However, iron mines in Goa remain in private hands even though the government controls the mines in India proper. Since the takeover, minimum prices for Goan ore have been set by the Indian government and price penalties are imposed unless a certain percentage of the ore is transported in Indian ships.

Goa is reported to contain over 300 million tons of ore of 58% iron content, with some deposits running as high as 65%. Two mines, Chowgule and Dempo, have been modernized with Japanese capital but the remainder operate quite primitively. The deposits are very close to the ocean, with some deposits being only 5 miles to port. From other areas, ore travels 8 miles by truck and 15 miles by river boat. The present loading facilities are not adequate but they are being improved with the help of the Japanese.

From the standpoint of possible low cost producers, Goa ranks with the best.

South America

Peru, Chile and Brazil are the three countries in South America supplying ore to Japan. Current shipments from Brazil are not significant but these are expected to account for most of the growth in the next few years. Although the ocean voyage to Japan from South America is longer than from other

competing sources, use of large size ore carriers has helped to offset this disadvantage.

Peru and Chile

The mines of these countries are all close to good ocean shipping ports and in terms of total transportation cost (ocean and overland) compare favourably to most other suppliers. The quality of the ore shipped is good and since the mines are already in production, there is no doubt that these producers can meet all competition. In most cases the mines are fully mechanized. Marcona of Peru is to be the first foreign pellet supplier to the Japanese market. The plant is already in production and shipments of 500,000 t.p.a. are scheduled to commence in 1964. Also, Marcona is the first shipper to employ ocean backhaul of crude petroleum to reduce the cost of ocean shipping to Japan.

The mines in these countries are in a position to meet stiff competition in the Japanese market, and it is anticipated that they will continue to maintain their sales to Japan at about the same annual volumes. The reported reserves for these countries are not large but at the present rates of production they are adequate for many years.

Brazil

Brazil, which has immense reserves of high grade ore, is expected to increase its shipments of ore to Japan at a fairly rapid pace. In 1962 the Japanese steel industry negotiated a contract with Brazil covering a 15 year period for the purchase of 50 million tons of ore grading 65 to 67% iron. Shipments are to commence April 1st, 1966, at 1 million tons, increasing to 2 million tons for the second and third years, 3 million tons for the fourth to seventh years, 4 million tons in the eighth to thirteenth years and 4.5 million tons in the fourteenth and fifteenth years. The contract stipulates that the ore must be available at a port which can handle ships with a capacity of 100,000 DWT.

Cia Vale do Rio Doce, S.A. is a Brazilian Government-controlled company. Its Itabira mine is located 350 miles from the port of Vitoria and the ocean voyage from there to Japan is 12,500 miles. Shipments from Brazil to Japan in 1963 were 500,000 M.T. Much of this ore was transported as ballast in passenger liners plying between the two nations. The port of Vitoria is currently being developed to accommodate super ore carriers which will service the ships in the Japanese trade under the contract commencing in 1966.

The import of Brazilian ore is contrary to the Japanese policy of obtaining supplies which do not have a heavy transportation burden. Ordinarily Brazilian ore would lie outside the normal sphere of supply. However, the balance of trade favours Japan and the Japanese are large investors in a new steel complex being established in Brazil. The Usiminas project is a Japanese - Brazilian joint venture with total expense estimated at $500 million. Seventeen leading steel and machinery manufacturing companies in Japan have participated in the project and at the end of 1962 had invested $27 million in construction and extended loans of about $99 million in the form of deferred payments on machinery and equipment imported from Japan. It is anticipated that further investment and loans will be granted.

The Canadian Trade Commissioner in Brazil comments, "Japanese investments in this country are so large that Japanese users of iron ore would, I suspect, be most unwilling to jeopordize the goodwill of the Brazilian government, which is essential to the successful operation of their investments, by diverting their iron ore purchases from this country to another." In this deal the Brazilian government is utilizing its own facilities to produce ore and selling this ore to obtain foreign exchange, while the Japanese purchasers are increasing their exports. This is an unbeatable combination and, barring complete political disintegration in Brazil, the growth of Brazil as a supplier of Japan appears assured. In circumstances such as these real economics are of little assistance in analyzing the competitive abilities of the ore supplier. As to the future position of Brazil as a supplier of ore, one can only say that Japan will purchase as politics dictate.

Venezuela

Venezuela has large reserves of high grade ore and has made offers to Japan. However, the Panama Canal can only handle 45,000 DWT tankers and the charge is about $0.40 per ton for transit so Venezuela's location is not an attractive one.

North America

In 1963 Japanese imports of iron ore from North America were 3.9 million tons which was almost equally shared by the United States and Canada. All of this ore was shipped through West Coast ports. Although shipments of ore are expected to maintain their share of the Japanese market at least until 1970, it is not anticipated that the mines now shipping to Japan will have any great influence in the Japanese market.

In British Columbia, the only Canadian area exporting to Japan, reserves are small and most of the mines will be depleted in a short time. The ore is shipped as a magnetite sinter feed. All of the deposits are located a few miles from tidewater and present no transportation problem, so it has been possible to bring these mines into production with a minimum of reserves. It is not beyond the realm of possibility that similar deposits may be found in the future to replace some of the depleted mines.

On the West Coast of the United States, reserves are fairly substantial but with the growth of existing steel mills and the possibility of future developments, it is postulated that these reserves may be diverted to local use. Although an increase in exports to Japan is anticipated before 1970, this is attributed to purchases of pellets. Except for these pellets, the quality of the ore purchased is low and the prices being paid are higher than normal. The mines are not located on the coast, as they are in British Columbia, and profit margins will certainly be reduced by the deteriorating prices.

Australia

Recent Developments in Australia

In the last few years Australia has emerged as the most important competitor for the Japanese iron ore market. The main reason for this sudden change is the relaxation of the iron ore export embargo.

Between 1938 and 1960, Australia prohibited exports of iron ore to conserve known deposits for local industry since it was believed that ore reserves were barely adequate for future national needs. In December, 1960, this embargo was partially lifted to permit controlled export from some deposits. In the next two years, exploratory work on deposits that had been known for many years raised the reserves in West Australia alone to an estimated 8 billion tons - enough to meet present world consumption for twenty years. The quality of the ore being found is excellent, being high in iron and low in impurities. The major Australian deposits are about 3,800 miles from Japan by ocean. Overland transportation to the sea varies, but the longest distance being considered is 270 miles, with several deposits being closer.

There is no doubt that Australia will become a major supplier of iron ore to Japan but only one token contract with Western Mining at Koolanooka has been finalized as yet. However, various companies in Australia have made offers of iron ore to the Japanese iron and steel industry totalling 20 million t.p.a. The strong competition between potential suppliers is resulting in offers of large volumes of ore at low prices over long contracts with, in one case, a price reduction written in for increased purchases. Negotiations on these offers is in progress at time of writing this report and a delegation from the Japanese steel industry is to visit Australia in June of 1964.

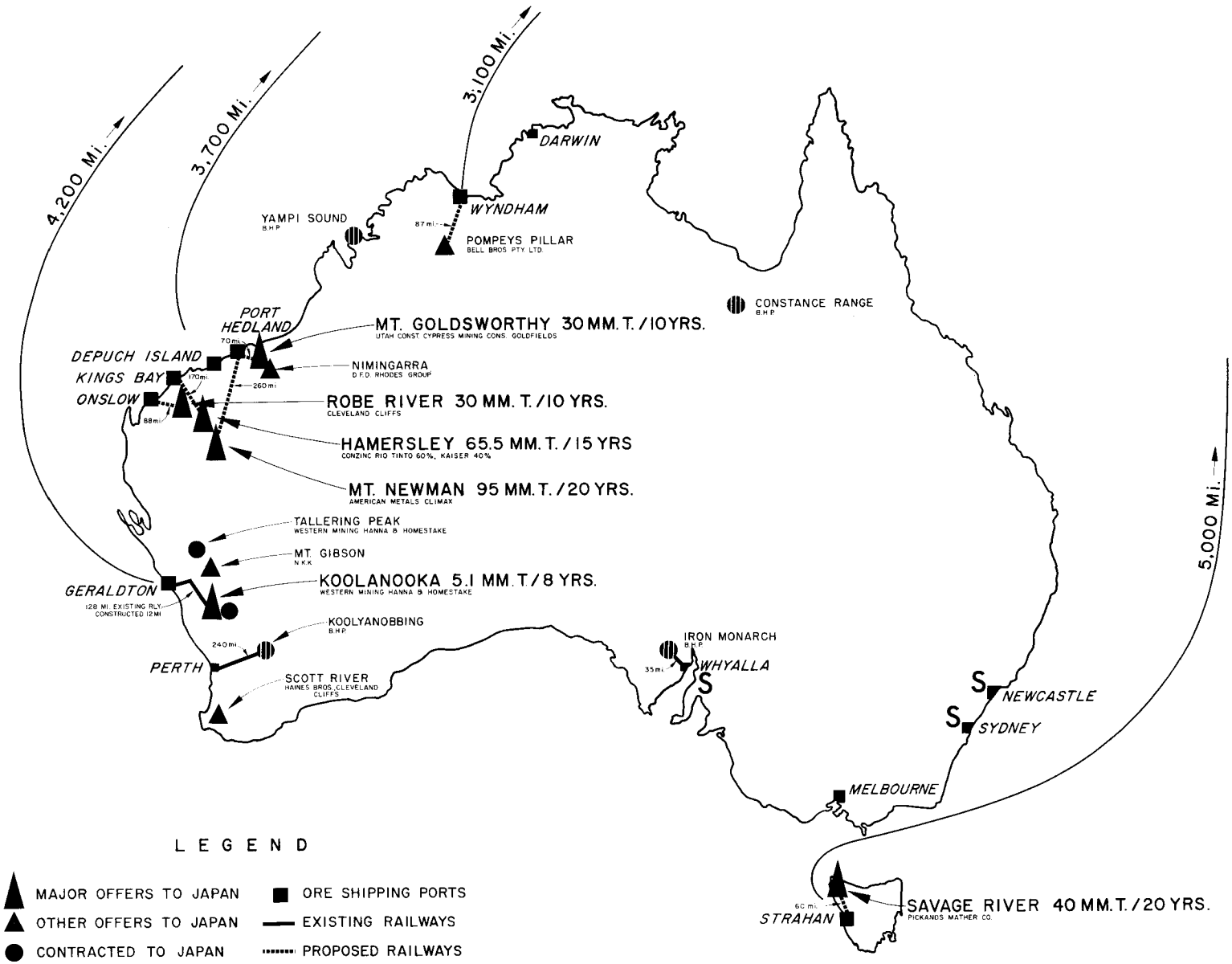
Australian Offers of Iron Ore to Japan
(Million M.T.)

Deposit	Status	1965	1966	1967	1968	1969	1970	1971	Term
Koolanooka	Contracted	-	0.5	0.5	0.6	0.6	0.7	0.7	5.1 ending 1973
Hamersley	Offered	-	-	1.5	2.0	3.0	4.0	5.0	65.5 ending 1981
Mt. Newman	Offered	-	-	-	-	2.0	3.0	5.0	95.0 ending 1988
Mt.Golds-worthy	Offered	0.5	1.5	2.0	3.0	3.0	4.0	4.0	(a)
Robe River	Offered	-	1.5	3.0	3.0	3.0	3.0	3.0	15 yr. contract
Savage River	Offered	-	-	2.0	2.0	2.0	2.0	2.0	40.0/over 20 yrs.
Mt. Gibson	Planned			0.5	0.5	0.5	0.5	0.5	Not announced
Francis Creek	Planned			0.3	0.3	0.3	0.3	0.3	Not announced
Total		0.5	3.5	9.8	11.4	14.4	17.5	20.5	

(a) 3 plans (1) 12.0/7 yrs. (2) 19.0/8 yrs. (3) 30.0/10 yrs.
Annual volumes shown are for maximum.

Australian developments are important not only as sources of a competitive supply but because the negotiations now taking place will set the pricing pattern for imports to Japan for many years to come.

AUSTRALIAN IRON ORE DEPOSITS



LEGEND

- MAJOR OFFERS TO JAPAN
- OTHER OFFERS TO JAPAN
- CONTRACTED TO JAPAN
- DOMESTIC DEPOSITS
- ORE SHIPPING PORTS
- EXISTING RAILWAYS
- PROPOSED RAILWAYS
- S STEEL MILLS

PRINCIPAL AUSTRALIAN DEPOSITS

KOOLANOOKA AND TALLERING PEAK

DEVELOPER: Western Mining

PARTICIPANTS: Western Mining 50%
Hanna Mining 25%
Homestake Mining 25%

LOCATION: Western Australia

RESERVES: 15,000,000 T. hematite

PRODUCT: Lump - Fe 60 (58)%; P. 0.15 (0.20)%
SiO_2 + Al_2O_3 10% max.

VOLUME: 5,100,000 in 8 yrs. commencing 1966

STATUS: Contracted

OVERLAND: Total distance - 141 miles by railway, 12 miles extension to be constructed to join existing railway.

PRICE: 21¢ per iron unit

REMARKS:

1. Contract concluded in autumn 1963.
2. The Japanese state that both the phosphorus and the price are high. The contract is the first in Australia and politics entered the negotiations. The price should not be considered as establishing a precedent.
3. The Western Australia government agreed to help the project by reducing the royalty from 67¢ to 17¢ in view of the poor economics of the project.
4. F.O.B. price estimated at $8.50 with freight at $4.10.

HAMERSLEY

DEVELOPER: Hamersley Iron Pty.

PARTICIPANTS: Conzinc Rio Tinto 60%; Kaiser Steel 40%

LOCATION: West Australia

RESERVES: 5,700,000 T. hematite
Mt. Tom Price reserves 560,000,000 T.

PRODUCT: 70% lump ore: 30% fine ore
Fe 64 (62)%; P. 0.06 Max.; SiO_2 + Al_2O_3 - 9.5% max.

VOLUME: 65,500,000 T. over 15 yrs. commencing 1967

STATUS: Negotiating

OVERLAND: New railroad of 170 miles would be constructed to Kings Bay.

OCEAN: 3,730 miles to Japan from Kings Bay.
Port to accommodate 65,000 - 100,000 D.W.T. vessels
Freight to Japan estimated at $2.40/T.

PRICE: Lump ore 20¢/Fe unit; Fine ore 17.5¢/Fe unit.
Reduction of 1¢ per unit if shipments increased to 7,000,000 t.p.a.

INVESTMENT: Total Investment estimated at $85 - $90 million.

REMARKS:

1. Export permit for 200,000,000 T. already obtained.

2. Price will be fixed for first 40,500,000 T. Price for balance will be adjusted considering the average price of other ores imported by Japan. But 2.5¢ differential between lump and fines is fixed.

3. Reported that pellet production is being considered.

AGREEMENT WITH GOVERNMENT: In June of 1963 Hamersley Iron Pty. Ltd. and the government of West Australia signed an agreement designed to create an iron ore export industry by the end of 1967, and a new integrated iron export industry by the end of 1992. This agreement is the fourth of its kind (and the biggest) to be signed by the State Government in the past four years. It emphasizes Western Australia's position as the world's fourth largest source of high-grade iron ore. The agreement gives Hamersley Iron prospecting rights on 2,600 square miles in the Hamersley Range area, with subsequent rights to take leases with a maximum total area of 300 square miles. The deposits are centred on Mt. Brockman, 110 miles south of Roebourne

Under the agreement Hamersley Iron Pty. Ltd. undertook to spend the following amounts:

1. $1.8 million by the end of next year on investigations to prove markets and to produce plans for the export of iron ore at the rate of at least 1,000,000 tons a year.

2. $68 million on all facilities necessary for ore exports, which must begin by the end of 1967. These will include a port ultimately capable of accommodating 100,000-ton ore carriers, a standard gauge railway to the port, and towns complete with power and water supplies.

3. $18 million on a secondary processing plant with a capacity to treat 2,000,000 tons of ore a year. Complete plans of this plant must be submitted to the Government within 10 years of exports beginning and the plant must be ready for production two years after that - by 1979 at the latest.

4. $90 million on an integrated iron and steel industry with a production capacity of at least 1,000,000 tons of steel a year. Complete plans for this industry must be presented within 20 years of the first exports, and production must be possible within a further five years.

If the company fails to reach the processing or steelmaking phases of the project, the Government has the right to seek other companies to take over, and if successful, to terminate the agreement. Hamersley is to forfeit all its fixed deposits including port, rail and other installations if the agreement is terminated. If the Government cannot find another company to take over the steelworks phase, Hamersley Iron will be free to export for a further 10 years, when the Government will again have the right to terminate the agreement within three years. This 13 year cycle will continue through the life of the agreement.

It has been estimated that overseas exports, subject to Commonwealth approval, could reach 5 million tons a year. On high-grade direct shipping ore, the bulk of exports, Western Australia will receive 7½% of the F.O.B. price with a minimum of 66¢ a ton. Lower royalties will be charged for lower grade ores. On ore processed within the state, the royalty will be at the standard processing rate of 17¢ a ton. The company will be charged rental when it chooses mineral leases up to a maximum total of 300 square miles of temporary prospecting reserves it now holds. Rentals will range from 39¢ an acre for the maximum area to 22¢ an acre for less than 100 square miles. On the basis of 5,000,000 tons of high grade exports a year, the rentals and royalties could yield the State $3.4 million annually.

MT. GOLDSWORTHY

DEVELOPER: Mt. Goldsworthy Mining Associates

PARTICIPANTS: Utah Construction, Cyprus Mining, Consolidated Goldfields Pty.

LOCATION: West Australia

RESERVES: 64,000,000 T.

PRODUCT: Lump and fines - Fe 64 (61)%; P. .09 max.; $SiO_2 + Al_2O_3$ - 5-9%

VOLUME:
1. 12,000,000 over 7 yrs. commencing 1965 - 100% lump
2. 19,000,000 over 8 yrs. commencing 1965 - 80% lump, 20% fines
3. 30,000,000 over 10 yrs. commencing 1965 - 70% lump, 30% fines

STATUS: Negotiating

OVERLAND: New railroad of 70 miles to Port Hedland.

OCEAN: 3,680 miles from Port Hedland to Japan.
Port to accommodate 20-30,000 D.W.T. vessels 1965/1966, and 30-55,000 D.W.T. vessels by 1967.
Freight estimated at $3.00/T. for 30,000 D.W.T. vessels.

PRICE: Lump - 21¢/unit; Fines - 18.5¢ per unit

INVESTMENT: $45 million

REMARKS:

1. Approved export of 64,000,000 T. at a maximum of 4,000,000 t.p.a.

2. Under agreement with West Australia Government M.G.M.A. agreed to:

   - Spend $750,000 on feasibility.
   - Exports must begin in 5 yrs. at a reasonable price.
   - Establish a port, wharf and loading facilities.
   - Build a standard gauge railway and necessary roads.
   - Build two towns, including houses, schools, police services, water and power.
   - Royalty value at 7.5% of F.O.B. value, increased 28¢/T. after 21 years.
   - Initial lease term 21 years with right of renewal.

   This agreement appears to have been written with Depuch Island as the port but this apparently has been changed to Port Hedland.

3. Ore size - Lump 6mm.- 100mm., Fines - Minus 6 mm.

4. Sales 50% on C.I.F. and 50% F.O.B.

MT. NEWMAN

DEVELOPER: Mt. Newman Iron Ore Co. Ltd.,

PARTICIPANT: American Metal Climax Inc.,

LOCATION: West Australia

RESERVES: 2,000,000,000 T. hematite

PRODUCT: Lump - Fe 64.6%; P. 0.05%; $SiO_2 + Al_2O_3$ - 4.2%

VOLUME: 95,000,000 in 20 yrs. commencing 1969

STATUS: Negotiating

OVERLAND: New railroad of 260 miles would be constructed to Port Hedland.

OCEAN: 3,680 miles to Japan from Port Hedland
Port to accommodate 40,000 D.W.T. vessels.
Estimated freight at $2.85/T.

PRICE: Estimated at 20¢ per Fe unit C.I.F.
AMAX's tentative offer was 15.5¢ per Fe unit F.O.B. but a feasibility study in progress might change this figure although they have assured the Japanese that the price will be no higher.

INVESTMENT: $118 million

REMARKS: AMAX plans to offer participation to both the Japanese and to the Australian public.

ROBE RIVER

DEVELOPER; Cleveland Cliffs Iron Company

PARTICIPANTS: Basic Material Co. which is owned 51% Howe Sound Co. and 40% by Garrick Agnew Pty. of Australia.

LOCATION: West Australia

RESERVES: 650,000,000 limonite - 55-57% Fe.

PRODUCT: Pellets - Fe. 64%; P. .03%; SiO_2 + Al_2O_3 8.1%

VOLUME: Up to 3,600,000 t.p.a. - 3,000,000 minimum - 10 years commencing 1966.

STATUS: Negotiating

OVERLAND: Construct new railway 88 miles to Onslow.

OCEAN: 3,760 miles to Japan from Onslow.
Port accommodate 60,000 D.W.T. vessels
Freight estimated at $2.75.

PRICE: 23¢ per unit based on 25% at cost and 75% at market price (see remarks).

INVESTMENT: $75 million.

REMARKS:

1. Financing is to be $26 million in equity and $49 million in debt. It is suggested that the Japanese subscribe for 25% of the equity with $6.5 million.

2. Cleveland-Cliff's management fee is to be 2% of the capital cost during construction and 1½% of F.O.B. value of production.

3. Price is to be determined on the basis of 75% of the production at market price and 25% at cost, which is estimated at 17¢-18¢ per unit. (Crest calculation: .75 (25¢) + .25 (17.5¢) = 23.1¢ per unit)

4. A sample of the pellets was sent to Japan.

SAVAGE RIVER

DEVELOPER: Pickands Mather and Company

LOCATION: Northwestern Tasmania

RESERVES: 300,000,000 T. - 38% magnetite

PRODUCT: Pellet - Fe. 67.5%; P. .02%; Al_2O_3 + SiO_2 - 1.75%; TiO_2 - 0.20%

VOLUME: 2,000,000 t.p.a. over 20 yrs. commencing 1967. Suggestion that 1,000,000 would be considered.

STATUS: Negotiating

OVERLAND: 60 miles by railroad or perhaps by pipeline to the terminus at Strachan.

OCEAN: 4,927 miles to Japan from Strachan. Port to accommodate 60,000 D.W.T. vessels Freight estimated at $3.30/T.

PRICE: 21.5¢ per unit based on 50% at cost and 50% at market (see remarks).

INVESTMENT: Net $51.5 million, $60 million total but government aid of $8.5 million for electric power is expected.

REMARKS:

1. Financing $39 million debt, $13 million equity, Japanese participation at 50% = $6.5 million.

2. Average price - 50% at cost 17¢ and 50% at market 25.5¢ - 21.25¢ per unit.

3. Costs of 17¢ per unit arrived at:

Operating cost	$ 5.93
Amortization and interest	2.24
Ocean freight	3.30
	$11.47/T.

4. Reported price on 1,000,000 T. 22.1¢ per unit.

5. The TiO_2 content has caused some concern in Japan although late reports suggest that it can be reduced to 0.20% in processing.

OTHER DEPOSITS

Mt. Gibson

No development company has been established. Iron Hill Mining Co. is the holder of the mining rights. Reserves in three ore bodies are estimated at 10 million tons of hematite ore with a grade of 62%. The deposit is 25 miles from the existing railroad to Geraldton.

A production rate of about 500,000 t.p.a. is contemplated and development by Kokan Mining is rumored with N.K.K. the purchaser.

Francis Creek

Northern Iron Mining has suggested a possible supply of between 300,000 and 700,000 t.p.a. Hematite ore would be mined from 9 deposits with an iron content of 60%. Sumitomo Metal Mining Co. is conducting a survey. The ocean distance to Japan is 3,060 miles.

Pompey Pillars

Bell Brothers Pty. have reserves of 15 million proven and 150 million estimated with an iron content 59% - 62% and P. of .06%. The deposit is located 87 miles from Wyndham and the ocean voyage to Japan is 3,060 miles. One report mentioned offers of 500,000 to 1,000,000 t.p.a.

Nimingarra

The R.F.D. Rhodes Group owns a deposit of about 50,000,000 tons of 58% - 62% Fe and .03% P. which is located about 50 miles from Mt. Goldsworthy and 180 miles from Depuch Island. It is reported that the feasibility of exploitation is uncertain and further prospecting is required.

Scott River

The Scott River deposit, which is owned by the Mineral Mining and Exports (W.A) Pty. Ltd., is reported to have reserves of 50 million tons of low grade ore which would provide 27,000,000 of high grade pellets. Export approval of 500,000 t.p.a. commencing 1965 has been obtained. However, the Japanese have not mentioned any negotiation on this project.

Summary

Competition for the Japanese market is keen and price reductions are taking place. The profit to iron ore producers is being reduced but for most there is no alternative market. Even if there were, similar conditions are being experienced throughout the world iron ore market.

Mines now supplying Japan can meet competition by reducing prices until the out-of-pocket costs of production are equivalent to income. The producing facilities have already been installed and the necessity of minimizing capital loss will compel operations to continue. Some producers have already recovered their capital and production will be continued at any operating profit. In operations where ore quality is not acceptable, the investment required to correct the quality deficiency must be viewed on an incremental basis. It is also possible that government assistance or tax relief might be available to producing iron mines in danger of suspending operations because of lower prices for iron ore. It is, therefore, unlikely that producing mines now selling iron ore to Japan would be forced out of the market by new suppliers undercutting their price.

Government owned deposits can withstand strong competition. Government ownership eliminates taxes and royalties and it also means that profits, although desirable, may not be considered in meeting competition. Foreign exchange requirements and plans for industrial development will dictate their policies.

Owners of new deposits attempting to enter the Japanese market are the major source of competition. Since it is a buyers market with numerous companies vying for a share of the imports, it is obvious that the Japanese will be able to negotiate the most favourable contracts as to price, quantity and term with those mines which will experience the lowest costs. The potential Australian producers are in this position and have the added advantage of being able to offer enormous reserves of high quality ore in a politically stable country. Although the Crest deposit has both the reserves and the political stability, the grade is lower, overland transportation is considerably longer and ocean shipping is slightly longer.

A comparison of the Crest project to that of several of the Australian deposits is presented in the section Evaluation of the Economics of Operation. This analysis shows that lower investment per ton of production and lower operating costs will give the Australian producers faster payouts on investment. It is apparent that Crest cannot gain entry to the Japanese market through cutting prices.

RECOMMENDATIONS

Development of the Snake River project depends upon being able to sell large volumes of ore to Japan. The grade of the ore rules out the possibility of selling lump ore and the expected trend in the Japanese consumption of blast furnace feeds precludes the marketing of sinter feed. The most readily saleable product will be pellets grading at least 65% Fe with a maximum of 0.07% P. Future beneficiation studies should be directed towards producing such a product. There is a possibility that either sponge iron or a related product may become saleable in Japan. Such a market may develop in response to technological or economic changes in the Japanese steel industry or the anticipated discovery of low cost hydrocarbons adjacent to Snake River may furnish Crest with an economic advantage which would permit the production of reduced material at a particularly competitive price. Nevertheless, a beneficiation technique which can economically produce a saleable product must be developed before sales of any type can be considered. There is no longer any possibility of developing a process in time to compete with the new Australian producers and future beneficiation studies should be conducted as economically as possible. Economical research in beneficiation is inevitably a protracted process since the work is done one step at a time to eliminate the waste which often occurs when several avenues are explored simultaneously. During the time it takes to develop an adequate process Crest should continue its market studies.

The summary of iron ore marketing in the preceding section is an accurate statement of conditions as of July, 1964. One need only consider the remarkable changes which have taken place in prices in the Japanese iron ore market during the past year to appreciate that such a summary is out of date almost as soon as it is written and to realize that continuing study is required to keep pace with developments. In view of the importance of accurate market data to any appraisal of Crest economics it is necessary that a real effort be made to keep Crest's knowledge of iron ore marketing accurate and current. Particular emphasis should be given to:

(1) Japanese ore prices,

(2) The relationship between anticipated demand and actual consumption,

(3) Changes in ore specifications such as trends toward pellets or partially reduced furnace feeds, and

(4) Changes in the competitive abilities of alternative producers.

The information relevant to these topics derives from our contacts with Japanese trading companies, with the Canadian trade commissioners in various countries and from technical journals both domestic and foreign. This information is best obtained on a continuing basis. One man should be assigned the specific duty of maintaining our information contacts and of reading, digesting and filing the information that is published in the technical journals. This one person would shortly become the only man with a working knowledge of marketing conditions. It is important that this man periodically review and write a full report on the current market status so that a transfer or termination to which all corporate employees are liable would not mean a complete loss of information to Crest. The reviews should be scheduled to coincide with the statistical releases of the Japan Iron and

Steel Federation's semi annual reports in March and September would also fit the corporate budget practice.

As long as the intention is only to keep our knowledge current without appreciably expanding its scope, the program outlined above can be accomplished by one person working half time. If special studies on some particular aspect are required then further time will be needed. It is not anticipated that this will be necessary until some improvement in the economics of the Crest project becomes apparent.