AN ABSTRACT OF THE THESIS OF

TED ANDREW ZDANOWICZ for the MASTER OF SCIENCE
(Name of student) (Degree)

in Geology presented on June 1, 1971
(Major) (Date)

Title: STRATIGRAPHY AND STRUCTURE OF THE HORSESHOE GULCH AREA, ETNA AND CHINA MOUNTAIN QUADRANGLES, CALIFORNIA

Redacted for Privacy

Abstract approved:
Dr. A. J. Boucot

The Horseshoe Gulch area includes 16 square miles in the Eastern Paleozoic Belt of the Klamath Mountains geologic province north of Callahan, California. Fossiliferous Late Ordovician and Silurian limestones and unfossiliferous greywackes, arkoses, shales, mudstones, schists, and phyllites, and other terrigenous clastic rocks are exposed in a broad fault zone in the area of study. It is concluded that the limestones represent a clear, stable, and relatively shallow water environment of deposition. These limestones are found associated with a geosynclinal sequence of rock units.

Eleven mappable units grouped into upper and lower thrust plates, are recognized.

The fault zone in the Horseshoe Gulch area, approximately one mile wide, is characterized by a prominent folded thrust fault that is

part of the Mallethead Thrust. The Mallethead Thrust, whose age is at least post-Late Silurian in the area, has placed upper plate unfossiliferous, pre-Cretaceous age chlorite grade metamorphic rocks over the Early Paleozoic unmetamorphosed limestones and clastics of the lower plate. The trace of the Mallethead Thrust is very sinuous and irregular.

Stratigraphy and Structure of the Horseshoe Gulch Area, Etna and China Mountain Quadrangles, California

by

Ted Andrew Zdanowicz

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1972

APPROVED:

Redacted for Privacy

Professor of Geology
in charge of major

Redacted for Privacy

Acting Chairman of Department of Geology

Redacted for Privacy

Dean of Graduate School

Date thesis is presented

Typed by Opal Grossnicklaus for Ted Andrew Zdanowicz

ACKNOWLEDGEMENTS

I wish to express my appreciation to the many individuals who have made a contribution to this study. To Dr. Arthur J. Boucot, my major professor, a very special thank you is extended for his guidance, assistance, field visitations, editing of the manuscript, and for financial support from NSF Grant GA 27350 for the field season.

I am also indebted to Drs. J. G. Johnson and Alan R. Niem for critical review of the manuscript and helpful suggestions.

Thanks are due to Dr. Anthony Wright, Wollongong University College, N.S.W. Australia, for his assistance and dating of the fossil corals. Thanks are also due to Dr. Carl B. Rexroad, Indiana Geological Survey, for conodont extraction and for dating of conodont-bearing limestone samples.

I wish to thank the property owners in the Horseshoe Gulch area for allowing me free access to their properties, and Mr. Rodney Gregg of Gazelle, California for valuable assistance in the field mapping for this project.

Sincere appreciation is extended to Mr. John Griffin, Mrs. Nancy Griffin, Dr. Donald Garlick, California State College, and to Mr. David Rohr, fellow graduate student and trailer-mate during the field season, for their field visitation and critical analyses of thin sections.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

STRATIGRAPHY AND STRUCTURE OF THE HORSESHOE GULCH AREA, ETNA AND CHINA MOUNTAIN QUADRANGLES, CALIFORNIA

INTRODUCTION

Location and Accessibility

The Horseshoe Gulch area of the eastern Klamath Mountains is located in the northeastern quarter of the Etna Quadrangle, and in the northwestern quarter of the China Mountain Quadrangle, Siskiyou County, California. The map area is approximately ten miles by road north of the town of Callahan and approximately ten miles by road southeast of the town of Etna, California. The thesis area, which encompasses 16 square miles includes parts of Townships 41 and 42 North and Ranges 7 and 8 West and lies approximately seven miles south of Duzel Rock (Figure 1).

The thesis area is readily accessible. Automobile access is provided by California Highway 3 to the mouth of McConaughy Gulch, from which a graveled road leads to the entrances of Horseshoe and Trail Gulches. Principal access into the thesis area is provided by this gravel road which extends from the mouth to the head of McConaughy Gulch. Since the smaller gulches like Horseshoe and Trail open into McConaughy Gulch; the area is within easy walking distance. A number of these smaller gulches can be traversed by

Figure 1. Index map of the state of California showing the location of the Horshoe Gulch Area in the Etna and China Mountain Quadrangles (black).

the use of privately owned jeep trails. Highway 3 intersects U. S. Interstate 5 just south of the town of Yreka, California.

Purpose and Methods of Investigation

The primary purpose of this study was to produce a detailed geologic map of the Horseshoe Gulch area and to unravel the Lower Paleozoic structure and stratigraphy of the known fossiliferous carbonate and unfossiliferous terrigenous beds of the area. A further objective of this study was to determine the relationship between the Lower Paleozoic sedimentary rocks and the associated and surrounding phyllitic rocks.

Field work began in late June, 1970 and was completed in mid-September, 1970. The surface geology was plotted in the field on U. S. Forest Service blue line topographic maps (1:7600) for the Etna and China Mountain Quadrangles, with the aid of aerial photographs. Wentworth's grain-size scale, dilute hydrochloric acid, hand lens, and Brunton compass were used for rock descriptions and attitude measurements.

Petrographic examination of 30 thin sections were made to confirm field observations along with 50 thin sections of corals which were used for age dating by Dr. Wright. Gilbert's classification of sandstones (1953) and Folk's classification of carbonate rocks (1968) were used for the sedimentary rocks. The classification of metamorphic rocks by F. J. Turner (1968) is used for this paper.

Previous Work

Wells et al. (1959) mapped an area extending from Yreka south to Callahan, which included Townships 40, 41, 42, 43, 44, 45 North and Ranges 6, 7, 8, 9 West. The work done by Wells et al. included mapping of the Horseshoe Gulch area at a scale of 1:312, 500. Churkin and Langenheim (1960) published the geology of the Payton Ranch area near Gazelle, Yreka Quadrangle, California at a scale of 1:50, 000. In 1962 Romey (in Davis et al.) published a map of most of the Etna Quadrangle at a scale of 1:50, 000. Romey's mapping included the rock units found at Facey Rock and those units which crop out south of Facey Rock towards Callahan.

Some of the limestones present in Horseshoe Gulch were dated by J. H. Johnson (1959, p. 157) on the basis of the occurrence of calcareous algae. Boucot in Berry and Boucot (1970, p. 153), noted the occurrence of probable Ashgill age limestones in Horseshoe Gulch.

Relief and Drainage

The lowest elevation in the area of investigation is 2900 feet near the mouth of McConaughy Gulch. The maximum elevation is 5475 feet at the summit of Facey Rock. Thus the maximum topographic relief is 2575 feet. The relief is greatest in the eastern and southern parts of the area of investigation.

For most of the summer there is little or no water flowing in the drainage of the area. However, during early spring, and after summer rainshowers intermittent streams flow from Horseshoe and Trail Gulches into McConaughy Gulch. The ultimate drainage of water in this area is into the Scott River.

Climate and Vegetation

The vegetation is generally characteristic of a semi-arid region, and the annual precipitation is about 30 inches (Irwin, 1960, p. 13). Most of the precipitation occurs during the winter months in this area, with only occasional showers during the summer. Vegetation is sparse and only the highest ridges are heavily timbered with such trees as fir and pine. Brush and poison oak are common locally and where they occur can be a deterrent to field work.

Exposure

Generally exposure is good on slopes and ridges, with the best exposures occurring on the sides of ridges. Mudslides and Quaternary alluvium tend to cover much of the floors of the gulches.

STRATIGRAPHY

Regional Stratigraphy

The rock types found in the Horseshoe and McConaughy Gulch areas are part of the unit which Irwin (1960) called the Eastern Paleozoic Province of the Klamath Mountains (see Figures 2 and 3). This Paleozoic belt according to Irwin, consists of a series of geosynclinal rocks including wackes, mudstones, cherts, semischists, limestones and phyllites. These rock units are thought to range from Upper Ordovician to Mississippian in age (Irwin, 1960, p. 16). This Eastern Paleozoic Belt is bounded to the west by what Irwin (1960, p. 17) called the Central Metamorphic Belt, and to the east by Tertiary and younger volcanics.

Stratigraphy of Horseshoe Gulch Area

The rock units which crop out in the Horseshoe Gulch area have been grouped into two distinct assemblages. In Horseshoe Gulch proper and extending to the gulches both north and south of Horseshoe is a sequence of unmetamorphosed Lower Paleozoic fossiliferous and unfossiliferous sediments referred to in the following pages and on the accompanying geologic map as the lower plate.

Thrust over these lower plate sediments are phyllites which lie above an undulating thrust surface. These phyllites are referred to in the following pages as the upper plate.

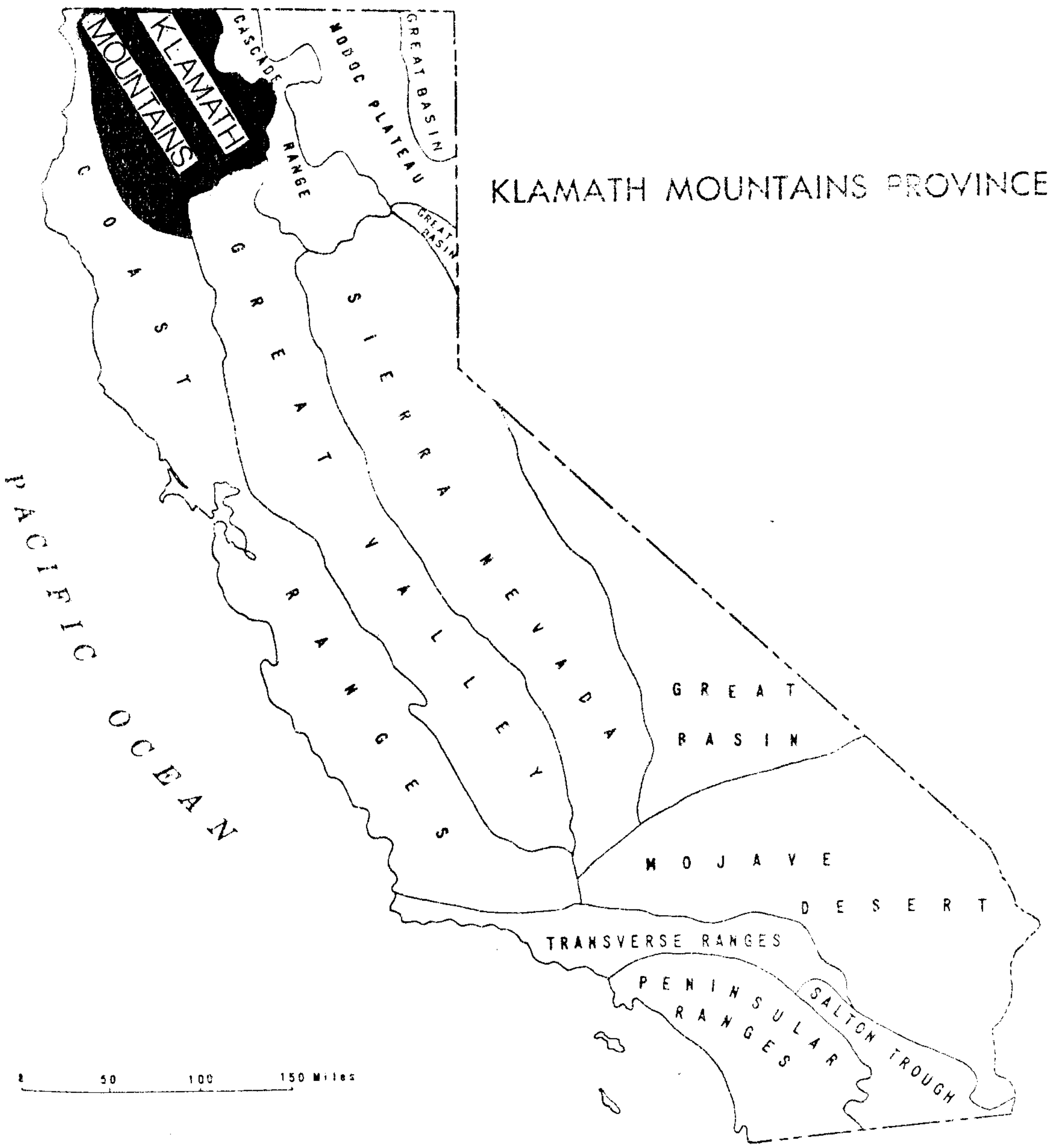

Figure 2. Index map showing the location of the Klamath Mountains Province in the state of California (after Irwin, 1966).

Location of Investigation

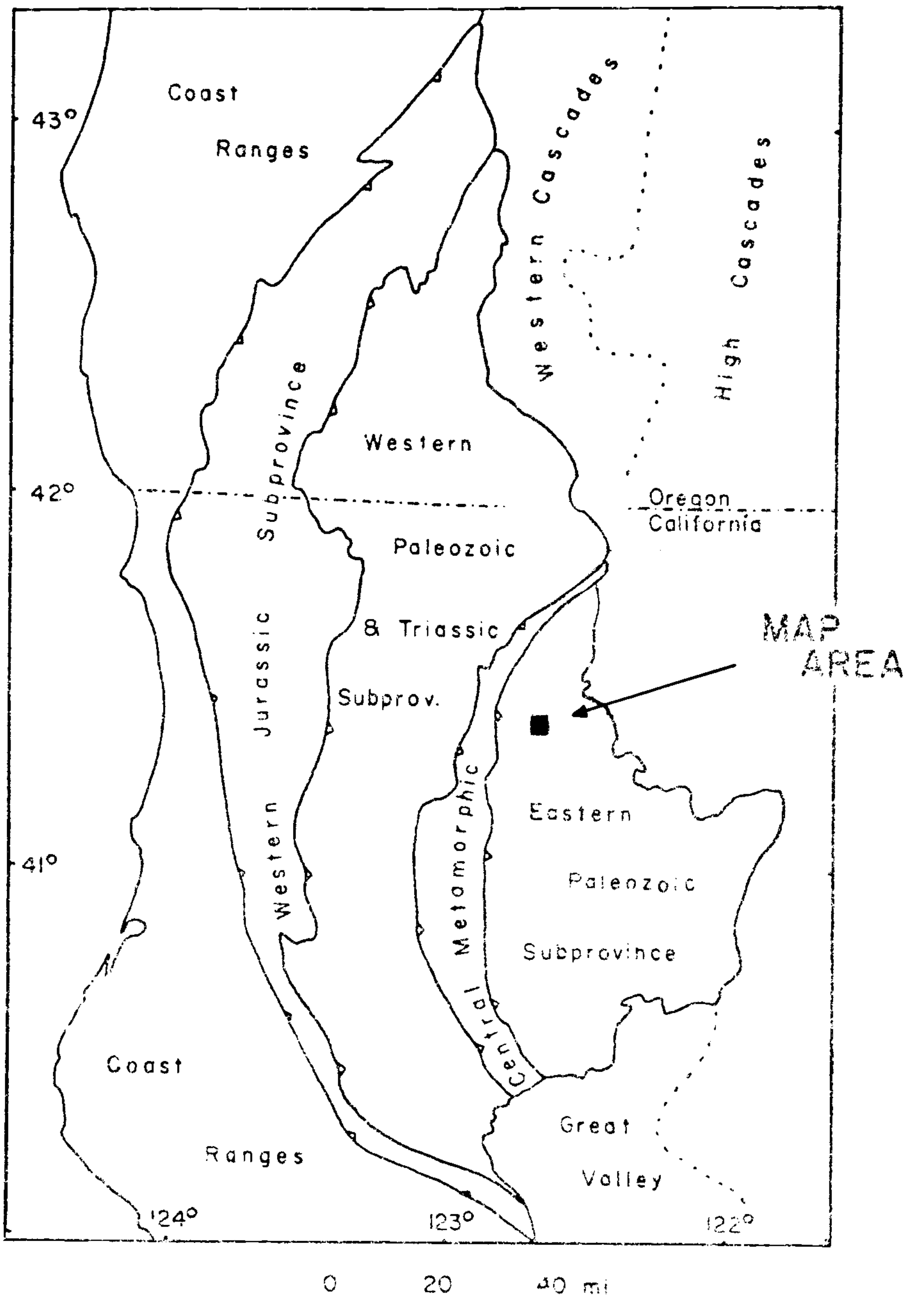

Figure 3. Index map showing study area, subprovinces of Klamath Mountains, and adjoining provinces (from Irwin, 1966).

Table 1 on a later page illustrates which rock units found in the area belong to the upper and lower plates.

Lower Plate Units

Horseshoe Gulch Limestone

Name

The name Horseshoe Gulch Limestone is introduced here for large, tectonic blocks of Late Ordovician (Ashgill) age limestone which crop out in Horseshoe Gulch, Etna Quadrangle, California.

Although limestones which notably crop out on Facey Rock, to the south of the thesis area, have been named the Facey Rock Limestone by Romey (1962, p. 949), this name is not used for the limestones found in Horseshoe Gulch because of major lithologic differences.

The Horseshoe Gulch Limestone is characterized by abundant chert and abundant wavy, partially silicified rounded calcareous organic matter which may possibly be algae, and by moderately abundant silicified tabulate corals as well as silicified brachiopods.

Distribution

The use of the name Horseshoe Gulch Limestone is restricted to those cherty limestone blocks which crop out in Horseshoe Gulch. Geologic mapping has shown that these Ashgill age, cherty limestones crop out only in Horseshoe Gulch, and this name is not intended for

Table 1. Upper and Lower plate units of the Horseshoe Gulch area, not meant to be in any stratigraphic sequence.

Upper Plate Unit	Stuart Fork Formation phyllites
	thrust fault = Mallethead Thrust
	Facey Rock Limestone
	Unnamed Silurian? Limestone Faulted into Phyllite
	Unnamed Silurian? Limestone
	Unnamed Silurian Limestone
	Horseshoe Gulch Limestone
Lower Plate Units	Unnamed Conglomerate
	Unnamed Calcareous Siltstone
	Unnamed Arkose
	Unnamed Shales and Feldspathic Wackes

other non-cherty limestone blocks which occur in gulches both to the north and south of Horseshoe Gulch. Similarly the non-cherty Silurian limestones which also crop out in Horseshoe Gulch are lithologically distinct from the Horseshoe Gulch Limestone.

Type Locality

The type locality of the Horseshoe Gulch Limestone occurs just to the north of the spring in the N $\frac{1}{2}$ of Section 3 of the NE $\frac{1}{4}$ of the Etna Quadrangle, R. 8 W., T. 41 N., California. Fossil locality Z-13 is located in this block of limestone.

Lithology

The Horseshoe Gulch Limestone consists of massive, fine grained limestone. The weathered surface exhibits a light gray color (N 7) with a pitted surface. Large cavities and solution channels are also present; the latter phenomena, along with the pitted surfaces, are due to solution of the limestones. On the weathered surface of the limestone one finds prominent brown to black chert nodules and fragments; commonly the remains of silicified fossils (Figure 4). Some brown iron staining is also visible on the weathered surface.

The fresh surface of the limestone exhibits a light bluish gray color. In some of the massive limestones, thin 1-2 cm. stringers

Figure 4. Prominent brown chert nodules on weathered surface which are very characteristic of the Horseshoe Gulch Limestone (Locality Z-13)

of light to dark brown silty material is interbedded with equally thin 1-2 inch limestone beds. Small, randomly orientated veinlets of medium to coarse grained calcite are present.

Petrography

Thin section studies show these limestone blocks to consist of varying proportions of micrite, sparry calcite cement, and both calcareous and siliceous biological allochems (brachiopod and algal? fragments). Using Folk's (1968) classification of limestones these limestones may be classed as biomicrosparites. The actual percentages of lime mud, sparite, fossil fragments, plagioclase, and detrital quartz grains appears below in Table 2.

The sparry calcite crystals which are both due to partial recrystallization of calcite mud, and pore filling, are euhedral and range in size from .03 mm to .75 mm. They show good rhombohedral cleavage and polysynthetic twinning. The plagioclase grains exhibit Carlsbad twinning and appear to be corroded and altering to calcite. The grain size of the plagioclase varies from .03 mm to .05 mm. X-ray diffraction, performed on the non-calcareous residues of this limestone, indicates the presence of the clay minerals chlorite and illite.

Accessory minerals recovered by heavy mineral separation include garnet, pyrite, zircon, and magnetite.

Table 2. Modal analysis (600 points) of the Horseshoe Gulch Limestone (Locality Z-1)

Constituent	Z-1 1 thin section (percent)
Micrite	60.5
Sparite	32.0
$CaCO_3$ fossils	4.5
SiO_2 fossils	1.5
Quartz (detrital)	1.0
Feldspar	0.4
Opaques	0.1

Environment of Deposition

The abundance of micrite in the matrix of the Horseshoe Gulch Limestone suggests a relatively quiet environment of deposition. The abundance of whole, unbroken calcareous organic matter (algae?), and associated unbroken shells of brachiopods and molluscs also indicates that little wave agitation occurred at the shallow site of deposition. The calcareous organic matter, which seems to resemble some of the algae (Dasyporella?) which Johnson (1959, p. 157) identified, if indeed algae would suggest a shallow depth of water. The lack of detrital material indicates a clear water environment hospitable to animal life.

Thickness

Nowhere in the thesis area can one find sedimentary contacts between the Horseshoe Gulch Limestone and the surrounding units, due to the fault contacts between the limestone blocks and the surrounding units. Therefore it is impossible to ascertain the original thickness of the Horseshoe Gulch Limestone. However, one of the vertically faulted blocks measured 700 feet normal to bedding.

Structural Relationships

The Horseshoe Gulch Limestone, comprising blocks which vary in size from blocks 10 feet × 5 feet to blocks measuring 1200 feet × 700 feet, have been faulted by vertical or near vertical movements into the surrounding rock units. A fault breccia is commonly observed at the contacts between the limestones and surrounding units. The faulting of the limestone blocks has resulted in the lack of a general strike or trend being present, although where bedding as suggested by the alignment of chert nodules, is visible in the limestones it is vertical or close to vertical.

Age

The first dates published for limestones cropping out in Horseshoe Gulch were by Wells et al. (1959, p. 646) as part of the description of their Duzel Formation. They considered the limestones present in Horseshoe Gulch as belonging to the Duzel Formation, and according to the authors a large and distinct coral and brachiopod fauna which was collected but only partially worked up contained two coral genera, *Catenipora* sp. and *Grewingkia* sp., which were thought to indicate an uppermost Ordovician age. The actual dating was done by H. Duncan of the United States Geological Survey (Strand, 1963) who felt that the fauna Wells et al. collected might possibly be Early Silurian. Unfortunately Wells et al. did not record on a map where their fauna was collected and it can only be assumed that their samples were taken from a locality near my locality Z-13.

Further dating of some of the limestones in Horseshoe Gulch was done by J. H. Johnson (1959, p. 157). Although Johnson incorrectly referred to these limestones as part of the Gazelle Formation he did date the Horseshoe Gulch Limestone as Late Ordovician(?) on the basis of the occurrence of the following calcareous algae: Vermiporella borealis, Girvanella problematica, and Dasyporella norvegica. Once again no exact locality has been plotted on a map and so it is assumed the area of collection is again close to locality Z-13. After identifying the specimens Johnson stated that two possibilities exist, namely, ". . . that the rocks from which the specimens were obtained are actually of Upper Ordovician age or that typical Upper Ordovician algae survived into Lower Silurian time in northern California."

Thus, up until 1963, the Horseshoe Gulch Limestones were of questionable Late Ordovician age. In 1963 Boucot collected a brachiopod fauna from the same block which I have labelled as fossil locality Z-13. Boucot concluded that the fauna was of Ashgill age (Berry and Boucot, 1970, p. 153).

This then was the extent of information known about the age of the limestone blocks in Horseshoe Gulch prior to the mapping and collecting which I did in the summer of 1970. It was during this summer that I discovered three more fossiliferous localities: Z-1, Z-12, Z-18, plus recollecting from Z-13.

The silicified brachiopods collected from these localities were identified by A. J. Boucot, and J. G. Johnson, while the silicified corals were identified by A. J. Wright.

The dates obtained indicate that the faulted fossiliferous limestone blocks which I have grouped together under the name Horseshoe Gulch Limestone are all of Ashgill age. This age determination has been made on the basis of the presence of the coral genus Grewingkia and the brachiopod genera, Anoptambonites, Brevilamula, Dicaelosia, and Spirigerina, an assemblage indicating an Ashgill age.

A complete list of the fauna collected by the author and identified by Boucot, Johnson and Wright is given in Appendix I.

Unnamed Silurian Limestone

Distribution

Along with the Horseshoe Gulch Limestone and the Unnamed Limestone blocks present in the area of investigation there are two massive and faulted Upper Silurian limestone blocks found in Horseshoe Gulch. This limestone unit is found only in Horseshoe Gulch itself.

Lithology

These massive, fine grained limestone blocks exhibit a dark bluish-gray (5 PB 5/2) weathered surface. The iron present in these limestones commonly results in a reddish brown weathered surface. Solution pits and cavities are quite abundant. Abundant silicified algae are present and commonly stand out with a reddish-brown color on the weathered surface. The fresh surface color is bluish-gray. Small, randomly orientated calcite veinlets are visible on both weathered and fresh surfaces.

This limestone unit was found to contain unidentified silicified algae and identifiable silicified and calcareous corals which were used to date this unit (Figure 5).

Figure 5. Abundant calcareous corals in the Unnamed Silurian Limestone. (Locality Z-22)

Petrography

Thin section studies show these limestone blocks to consist of varying proportions of micrite, sparite, and fossil fragments along with minor amounts of detrital quartz, magnetite, and authigenic plagioclase. The percentages of all of these constituents appear in Table 3. The ratio of sparite to micrite shows a slight variation between thin sections and as such this limestone unit appears to vary from a well sorted biosparite to a biomicrosparite (Figure 6).

X-ray diffraction, performed on the non-calcareous residues of this limestone indicates the presence of the clay mineral illite.

Accessory minerals recovered by heavy mineral separation include garnet, zircon, pyrite, and magnetite.

Environment of Deposition

The abundance of unbroken algae and corals suggests a shallow water environment of deposition.

Thickness

The limestone blocks of this unit are bounded by faults rather than sedimentary contacts. Thus actual thickness determinations are impossible. But using the attitude of one of the blocks a minimum thickness of 150 feet is indicated.

Table 3. Modal analysis (600 points) of the Unnamed Silurian Limestone unit (Localities Z-22 and Z-23)

Constituent	Z-22 1 thin section (percent)	Z-23 1 thin section (percent)
Micrite	59.7	33.4
Sparite	21.0	50.8
$CaCO_3$ fossils	15.3	14.8
SiO_2 fossils	3.7	0.7
Quartz (detrital)	--	--
Feldspar	0.2	0.2
Opaques	0.1	0.1

Figure 6. Photomicrograph showing greater abundance of micrite to sparite and fossil fragments, in the Unnamed Silurian Limestone (magnification 100 X) (Locality Z-22)

Structural Relationships

The faulted limestone blocks of this unit, which measure 150 feet X 350 feet, appear to be the result of faulting into the surrounding units.

Age

A. J. Wright identified the corals *Fletcheria* sp. and *Tryplasma* sp., which he regards (written communication, 1971) as indicative of a Late Silurian age for this unit. J. G. Johnson (oral communication, 1971) points out that these two coral genera have been reported in the Great Basin in beds as young as Early Devonian.

However this limestone unit has been assigned a Late Silurian, Ludlow age by Rexroad of the Indiana Geological Survey (written communication, 1971), on the basis of the conodonts which he found in this unit and which are included in Appendix I.

Unnamed Limestone

Distribution

Blue-gray, massive, non-cherty, faulted limestone blocks crop out extensively in the gulches both north and south of Horseshoe Gulch. These limestone blocks have been faulted into both the arkosic wacke and the feldspathic wacke rock units of the lower plate.

Lithology

The weathered surface of these limestones exhibits a light gray color (N 7). Solution pits and cavities are abundant and the result of solution activity. These massive fault blocks of limestone are fine grained and commonly contain silty lenses.

The fresh surface color is bluish-gray. Small veinlets of medium grained calcite are present.

These limestone blocks differ from the Horseshoe Gulch Limestone and the Unnamed Silurian Limestone by their lack of megafossils (either silicified or calcareous) and by the scarcity of chert nodules.

Petrography

Thin section studies show these limestones to generally consist of calcite crystals ranging in size from .05 mm. to 2 mm. These blocks are essentially made up of sparite although remnants of unrecrystallized micrite are occasionally present. Also present are detrital quartz grains, magnetite grains, and authigenic plagioclase. The amounts of these minerals and the proportions of sparite and micrite is given in Table 4.

Petrographic examinations indicate that these limestone blocks should be classified as coarsely crystalline.

Thin sections do illustrate one very important feature about

Table 4. Modal analysis (600 points) of the Unnamed Limestone Unit (Localities Z-2, Z-4, Z-5, Z-9).

Constituent	Z-2 1 thin section (percent)	Z-4 1 thin section (percent)	Z-5 1 thin section (percent)	Z-9 1 thin section (percent)
Micrite	7.5	26.9	19.5	45.0
Sparite	92.3	72.9	75.2	51.5
$CaCO_3$ fossils	--	--	--	--
SiO_2 fossils	--	--	--	--
Quartz (detrital)	--	--	5.0	2.5
Feldspar	--	--	--	--
Opaques	0.2	0.2	0.3	1.0

these limestones. These limestones exhibit cataclastic effects in the form of badly sheared and deformed calcite crystals (Figure 7). These features I conclude are the result of the limestones being sheared and thrust faulted into the surrounding rock units. The movement of these limestones has produced the deformed crystals.

Thickness

None of the limestone blocks which make up this unit are in sedimentary contact with the surrounding rock units. It is therefore once again impossible to ascertain the actual thickness of this limestone unit. However, one of the vertically faulted blocks measures 350 feet normal to bedding.

Structural Relationships

The massive limestone blocks of this unit which vary in size from 10 feet × 5 feet to 350 feet × 1300 feet have been faulted by vertical or near vertical movements into the surrounding rock units in the same manner as the Horseshoe Gulch Limestone blocks have been faulted into the arkosic wacke and the feldspathic wacke. A fault breccia is commonly seen at the contacts between the limestones and surrounding units. The faulting has destroyed the original trend of this limestone unit, but where present bedding is vertical or near vertical.

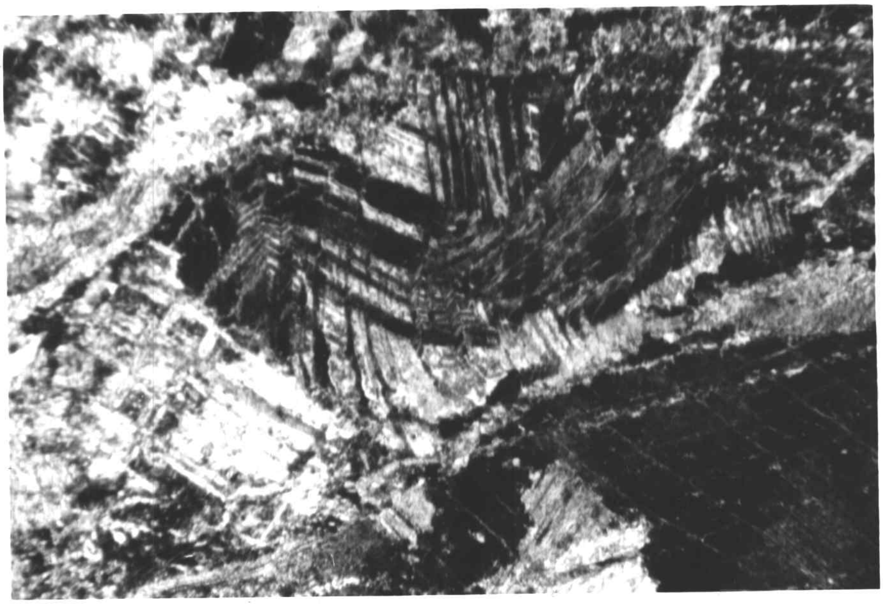

Figure 7. Deformed and bent crystals of calcite characteristic of the Unnamed Silurian? Limestone unit (magnification 100 X) (Locality Z-5)

Age

No megafossils have been found in these limestone blocks but numerous samples were examined for conodonts. The conodont work done by C. Rexroad of the Indiana Geological Survey has produced one single specimen of Panderodus simplex whose range is from the Ordovician through essentially all of the Silurian (Rexroad, written commun., 1970). Lithologically this limestone unit closely resembles the Silurian Limestone blocks found in the area and thus this unit is considered to be of Silurian(?) age. The results of conodont studies on samples of this unit and other limestone units is included in Appendix I.

Facev Rock Limestone

Name and Distribution

The Facey Rock Limestone is a fine grained, massive, blue-gray cliff forming limestone named by Romey (1962, p. 949) that crops out just north of Facey Gulch. Romey also included the limestone bodies which occur at Limekiln and Messner Gulches as part of the Facey Rock Limestone. I mapped only a portion of the limestone block occurring at Facey Gulch and did not visit or map any other limestone bodies which Romey included as part of the Facey Rock Limestone.

Lithology

The weathered surface of the Facey Gulch Limestone exhibits a light gray color (N 7). Solution pits and cavities are abundant. Rare interbeds of argillaceous silt are present. The fresh surface color is blue-gray (5 B 7/1). Numerous calcite veinlets are present in this unit.

Petrography

Thin section studies show these limestones to generally consist of calcite crystals ranging in size from .03 mm to 0.5 mm.

The presence of minor micrite, abundant sparite, and rare crinoid fragments indicates that this limestone should be classified as a biomicrosparite. The percentages of these constituents appears in Table 5.

Thickness

No measurements of thickness were made by the author, but Romey (1962, p. 949) estimated the Facey Rock Limestone to have a maximum thickness of 300 feet.

Structural Relationship

Romey (1962) indicated that the block of limestone present at Facey Gulch overlies the surrounding mudstones and wackes. On his

Table 5. Modal analysis (600 points) of the Facey Rock Limestone Unit (Locality Z-15)

Constituent	Z-15 1 thin section (percent)
Micrite	20.8
Sparite	78.1
$CaCO_3$ fossils	1.0
SiO_2 fossils	----
Quartz (detrital)	----
Feldspar	----
Opaques	0.1

geologic map he indicated the Facey Rock Limestone blocks to be klippen. He thus implied that the limestone blocks have been thrust faulted over the surrounding rocks. This suggests a completely different structural interpretation for these Facey Gulch Limestone blocks than any of the other limestone blocks which I have mapped to the north. Only a few days were spent at Facey Rock and a detailed examination of the fault breccia between the Facey Rock Limestone block and surrounding rock units was not made, but I see no reason why this massive limestone block could not have been faulted into the surrounding siliceous mudstone by vertical or near vertical faulting in a fashion similar to the interpretation of the blocks in Horseshoe Gulch. From my mapping I have concluded the Facey Rock Limestone to be part of the lower plate. It would seem reasonable that all limestone blocks which are part of the lower plate and bounded on all sides by fault contacts in this local area have a similar structural origin. Obviously more detailed work will have to be done before arriving at a satisfactory conclusion as to whether the origin of the Facey Rock Limestone blocks is different from the Horseshoe Gulch Limestone blocks.

Age

No fossils have been found in the Facey Rock Limestone. Thus no age dates can be given for the Facey Rock Limestone, but because it is concluded that these limestones are part of the lower plate and because this unit has lithologic similarities to the known Silurian limestone, the Facey Rock Limestone is concluded to be of Silurian(?) age.

Unnamed Silurian(?) Limestone Faulted into Phyllites

Distribution

Slivers and fault blocks of limestone are observed to be caught up in the Stuart Fork phyllite of the upper plate, on the west side of the thrust fault contact between upper and lower plates. The faulted limestones are found from the head of McConaughy Gulch south to Trail Gulch.

Lithology

The weathered surface color is blue-gray (5 B 7/1) commonly accompanied by silty lenses on the surfaces of these fault slivers. Fresh surface color is blue-gray. These limestone blocks are commonly massive and fine grained and have not yielded fossils. There are rare, well laminated blocks. Close field examination of the limestone blocks indicates that recrystallization has occurred. These limestone blocks appear to be crushed and sheared due to their fault origin.

Petrography

Thin section studies show these limestone blocks and slivers to consist almost entirely of calcite crystals ranging in size from .05 mm to 2 mm. These blocks consist almost entirely of sparite, although minor amounts of micrite are still present. Authigenic plagioclase is also found. The amount of these constituents is given in Table 6.

Some of the calcite crystals are sheared and deformed and appear quite similar to the deformed crystals found in the Unnamed Limestone blocks.

Petrographic examinations indicate that these limestones should be classified as coarsely crystalline.

Thickness

All of these blocks have been faulted into the phyllites and thus no sedimentary contacts exist. Maximum width of these blocks is 250 feet, from which it is concluded that this limestone unit has a minimum thickness of 250 feet.

Structural Relationships

These sheared limestone blocks and slivers vary in size from slivers 3 feet × 5 feet to blocks 250 feet × 600 feet. It should be noted

Table 6 Modal analysis (600 points) of Unnamed Silurian Limestone Faulted into the Phyllites (Locality T-27 A).

Constituent	T-27 A 1 thin section (percent)
Micrite	9.9
Sparite	88.0
$CaCO_3$ fossils	----
SiO_2 fossils	----
Quartz (detrital)	1.0
Feldspar	1.0
Opaques	0.1

that they are unmetamorphosed as contrasted with the closely associated Stuart Fork phyllites. Because these limestones are not marbleized, as they would be if subjected to the same degree of metamorphism as the phyllites, it is concluded that they are part of the lower plate and not brought into the area along with the phyllites as part of the Mallethead Thrust. As a result we find lower plate limestone faulted at the time of thrusting into and surrounded by upper plate phyllites.

Age

No fossils have been found in these limestone blocks. Without fossils a precise age date cannot be assigned, but field observations have shown these limestone slivers to be lithologically very similar to the known Silurian blocks in the area. Thus this unit is assigned a Silurian(?) age.

Unnamed Arkose

Distribution

Dark brown quartz rich, unbedded, feldspathic rocks crop out in a narrow belt in Horseshoe Gulch and extend approximately in a north-south direction as far south as Trail Gulch and as far north as the head of McConaughy Gulch. This unit is bounded on the west by the Stuart Fork phyllites and on the east by the Unnamed Shales and Feldspathic Wackes unit. Similar rocks are unknown elsewhere in this region.

Lithology

A dark reddish-brown, weathered surface is seen in the outcrops. Most of the outcrops of the unit occur as large, prominent crags which are visible from a distance. These outcrops weather and break down to granules on exposed surfaces. In some places differential weathering has occurred which results in prominent quartz grains projecting above the surface. The iron minerals are very easily and extensively weathered in places producing a yellowish brown (10 YR 4/2) surface color.

The fresh surface exhibits a dark greenish brown colored matrix surrounding angular to subrounded quartz grains. The quartz grains appear to be poorly sorted and range in size from fractions of a mm to 5 mm in diameter.

The lithology and texture of this rock unit in the outcrops was such that it was uncertain whether the rock was of sedimentary or igneous origin. Hand specimens of this unit tend to exhibit both a "granitic" and "arkosic" appearance, and the origin of this unit was not resolved in the field. However, petrographic examination discussed below did show that this unit is of sedimentary origin.

Petrography

Thin section studies indicate the major minerals of this rock unit to be: angular and subrounded quartz grains, large crystals of albite, and the chlorite mineral penninite which exhibits a prominent anomalous "Berlin Blue" birefringence. Accessory minerals are magnetite and hematite.

The matrix surrounding the quartz and albite crystals is essentially made up of iron rich platy minerals. The platy minerals that I was able to identify in the matrix are penninite, and possibly halloysite, and/or kaolinite. The albite grains show extensive corrosion and weathering to clay minerals. The rock is poorly sorted.

This rock unit is considered to be of sedimentary origin on the basis of its subrounded quartz and albite grains, the surrounding matrix, and the sorting (Figure 8).

The percentages of the major minerals are given in Table 7. Using the classification of impure sandstones and wackes proposed by Williams, Turner, and Gilbert (1953, p. 292) this is classified as an arkosic wacke.

Thickness

The field mapping of this unit did not indicate any bedding being present at all. Nothing is known about the internal structure or

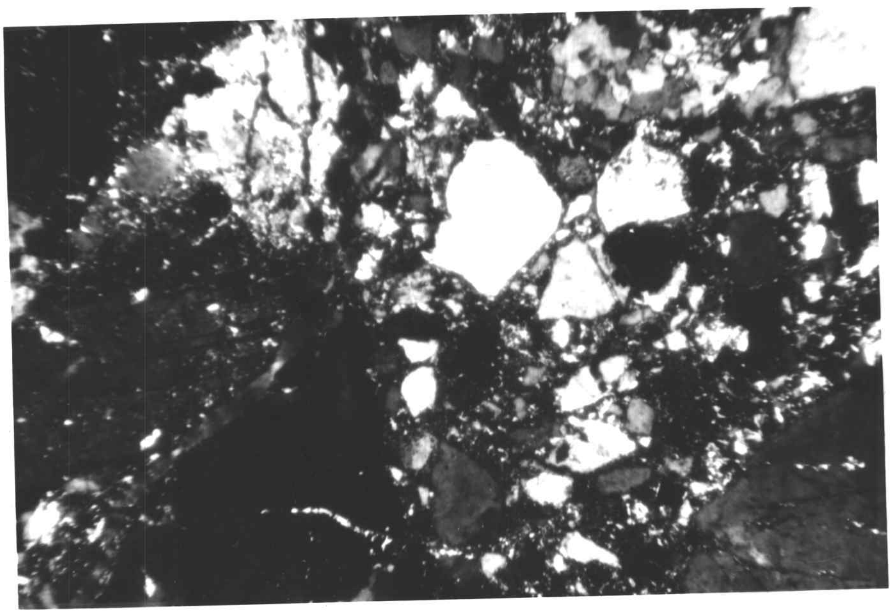

Figure 8. Angular, common and composite quartz (Q), and Feldspar (F) set in a microcrystalline clay matrix. A sedimentary origin is suggested by the fragmentary nature of these mineral constituents (magnification 100 X). (Locality T-24)

Table 7. Modal analysis (600 points) of the Unnamed Arkose

Constituent	T-3 1 thin section (percent)	T-24 1 thin section (percent)
Quartz	32	35
Feldspar	66	63
Rock fragments	2	2

thickness for the arkosic wacke. However, if this unit is dipping close to vertical, as the surrounding units do, then the mapping, which yields a maximum width of 4000 feet for this unit, indicates that the arkosic wacke has a minimum thickness of 4000 feet.

The contact with the phyllites to the west is concluded to be a thrust fault contact and the contact with the shale-sandstone unit to the east is also a fault contact. The arkosic wacke is not bounded by any sedimentary contacts.

Age

The age of the arkosic wacke is not known precisely, but thrust up through the arkosic wacke are some of the massive, faulted Horseshoe Gulch Limestone blocks which have been dated as being Upper Ordovician (Ashgill) age (p. 16). Thus because of the close association with the Horseshoe Gulch Limestone this arkosic wacke is considered to be Early Paleozoic(?) in age.

Unnamed Shales and Feldspathic Wackes

Distribution

This fine to medium grained shaly to sandy rock unit, bounded on the west by the arkosic wacke and on the east by the phyllites occurs as a north-south trending unit extending from Trail Gulch to the head of McConaughy Gulch.

Lithology

This unit, as it is depicted on the enclosed geologic map, includes both fissule blue-gray shales, and brownish-green quartz feldspar resistant sandstones and siltstones. Outcrops are commonly small and scattered. The fresh surface color is olive green. In some places sandstone blocks 1 to 5 feet in diameter are surrounded by shaly material.

Petrography

Thin section studies indicate that the sandstones of this rock unit are made up of angular grains of quartz, stretched plagioclase, chert, lithic rock fragments, muscovite, biotite, and a minor amount of chlorite. The accessory mineral hematite is present in minor amounts. The plagioclase appears to be altering to clay minerals. The rock displays moderate sorting, and contains approximately 12% argillaceous material.

The percentages of these main constituents are given in Table 8. Using the classification of impure sandstones and wackes proposed by Williams, Turner, and Gilbert (1953, p. 292) this rock is classified as a feldspathic wacke.

Structure and Thickness

Attitudes were obtained at numerous outcrops and these

Table 8. Modal analysis (600 points) of Unnamed Shales and Feldspathic Wackes.

Constituent	T-29 (percent)	T-30 (percent)
Quartz	78	85
Feldspar	20	12
Rock fragments	2	3

measurements indicate a general strike of N 30° E and a dip which varies from 50°-70°, to the west for this unit.

Since this unit is bounded by faults on both sides it is not possible to give an accurate thickness. However, using the dips of the beds and maximum outcrop width the minimum thickness is 4800 feet.

Age

The age of this feldspathic wacke is not know, but thrust up through this unit are some of the massive, faulted Horseshoe Gulch Limestone blocks which have been dated as being Late Ordovician (Ashgill) age (p. 16). Because of this association with the Horseshoe Gulch Limestone the feldspathic wacke is considered to be Lower Paleozoic(?) in age. Further evidence for considering this unit as well as my other clastic units of the lower plate as being Lower Paleozoic(?) is because of the general similarities of these rocks to dated clastic rocks found in the Gazelle area (Churkin, 1960).

Unnamed Conglomerate

Distribution

This unit composed of rounded pebbles and cobbles of limestone and "granitic" like material is found only at one locality to the north of Horseshoe Gulch.

Lithology

This unit is composed of a variety of moderate to well rounded pebbly clasts bound together by a dark brown clastic matrix (Figure 9). The weathered surface varies according to the type of surface material being examined. The limestone cobbles, which vary in size from 1 cm to 25 cm, have a light gray weathered surface color (N 7). The limestone cobbles contain cavities; the result of solution activity. The matrix weathers to a green-brown surface color and, because of its resistance to solution activity, it stands out in relief compared to the limestones. The igneous cobbles weather to a light gray color (N 7) and are also resistant to weathering.

The fresh surface of the limestone cobbles is a blue-gray color (5 B 7/1). The fresh surface of the igneous cobbles is a yellow-white color. The matrix exhibits a dark brownish-black color (5 YR 2/1) on its fresh surface.

Petrography

Thin section studies indicate the matrix consists of subrounded, poorly sorted quartz grains, zoned plagioclase crystals, which in places are being replaced by calcite, and platy minerals like biotite and chlorite. Accessory minerals include magnetite and pyrite.

Examination of the limestone cobbles indicates a silty limestone

Figure 9. Rounded limestone and igneous cobbles of the Unnamed Conglomerate unit, set in a dark brown clastic matrix (Locality T-15)

which would be classified as a biomicrosparite because some fossil (crinoid) fragments are visible. These limestone cobbles are very similar to the massive fault blocks of the Ordovician and Silurian limestone present in the area of investigation and it is likely that these cobbles are derived from the same units as the massive blocks.

The igneous cobbles are primarily composed of fine grained quartz, orthoclase, plagioclase, and minor amounts of muscovite and biotite. The composition of these cobbles generally resembles that of granodiorite. The plagioclase in these igneous cobbles is generally subhedral in form. The texture of these cobbles is generally hypidiomorphic granular. In some cobbles the even grained intergrowth of albite with orthoclase suggests that some of the cobbles may have originated from aplite or alaskite-like dikes.

Structure and Thickness

No attitudes were observed in this unit. It is surrounded on all sides by the phyllites of the Stuart Fork Formation and it is concluded that the conglomerate has been faulted up into the phyllite. This conglomerate exposure probably originated from a unit present below the thrust plane.

It is impossible to determine thickness, but maximum width of this single outcrop is 200 feet. This suggests a minimum thickness of 200 feet.

Age

Although some of the limestone cobbles were found to contain fossil fragments efforts to extract fossils to date this unit were unsuccessful. The age of this unit is unknown, but because the limestone cobbles appear very similar to the massive Upper Ordovician and Silurian(?) limestone fault blocks in this area this unit is assigned an Early Paleozoic(?) age.

The occurrence of cobbles resembling granodiorite is significant in that if these cobbles are Early Paleozoic or older this suggests a pre-Jurassic granitic basement underlying these geosynclinal sediments.

If such a basement exists theories postulating that this area has been affected by active sea floor spreading, will have to take this occurrence into account.

Unnamed Calcareous Siltstone

Distribution

This unit, mapped by Romey (1962), crops out north of Callahan and commonly surrounds many of the Facey Rock Limestone blocks. The calcareous siltstone which I have mapped occurs to the south of Trail Gulch and is in fault contact with the Facey Rock Limestone as shown on the geologic map (Plate 1).

Lithology

This rock unit, as mapped by me, consists primarily of calcareous siltstone and mudstone, but does grade into fine grained wackes locally. Weathered surface color is gray-brown (5 YR 6/1). Iron stains are present. Fresh surface color is blue-gray (5 B 7/1). Beds up to 5 mm in thickness are common.

Petrography

Thin section studies indicate that the rock is made up of abundant lath-like, poorly sorted, angular, plagioclase crystals, quartz, calcite, and muscovite which is often seen altering to chlorite. Accessory minerals include hematite and magnetite. The cement is calcareous and calcite crystals appear to be replacing the plagioclase grains.

Thickness

It was not possible to obtain any thickness determinations for this unit.

Structure

This rock unit is different from any of the other lower plate lithologies found to the north in Trail and Horseshoe Gulches described above. It has no general north-south alignment as do the other lower plate units. It seems likely therefore that this unit is separated from the Unnamed Arkose and Unnamed Shales and Feldspathic Wackes by a major fault. This supposed fault was not observed at any locality, but its trend, as shown on the map, is approximate and inferred.

John Griffin (oral communication, 1970), mapping at Duzel Rock and Moffet Creek, has found a similar calcareous siltstone which he believes occurs as a thrust plate emplaced prior to the thrusting of the Mallethead Thrust. The author did not note any evidence which either supports or negates the possibility of this unit being a thrust plate, but it should be considered as a possible explanation of the structural position of this unit until further work is done.

Age

No fossils were found in this rock unit, but its close fault association with Lower Paleozoic limestone blocks indicates a probable Early Paleozoic? age for this unit.

Upper Plate

Stuart Fork Formation

Name

Romey (1962, p. 937) applied the name Stuart Fork Formation to quartz-mica phyllites which he mapped on the west side of the Scott

River Valley. The author visited some of Romey's phyllite localities and found the Stuart Fork phyllites to be very similar to the phyllites found in the upper plate of the Horseshoe Gulch area. Hence the name Stuart Fork Formation is used for the upper plate phyllites found in Horseshoe and McConaughy Gulches.

Distribution

Dark green, quartz-chlorite rich phyllitic rocks crop out extensively and form the characteristic rock type throughout most of McConaughy Gulch and to the east, north, and west of Horseshoe Gulch.

The author has mapped only those phyllites which occur in the McConaughy Gulch thesis area, but according to Romey (1962, p. 937) similar or equivalent phyllites, to which he has given the name Stuart Fork Formation crop out on the west side of the Scott River.

Lithology

Dark, blue-green fine to medium grained quartz and chlorite rich phyllites constitute the major rock unit of the Stuart Fork Formation. The dark blue-green weathered surface of the phyllites exhibits a silky sheen which is characteristic of the phyllite and is primarily due to the presence of the mineral chlorite on planes of schistosity. Most outcrops of phyllite are extensively weathered and tend to break down to small fragments. The weathered surface also shows prominent brown iron staining. Many randomly orientated coarse crystalline quartz veinlets, ranging in size from a few mm to a few cm, are found in the phyllite.

The fresh surface displays a dark greenish gray color. Small voids, fractions of a mm in diameter, appear to be due to dissolved carbonate.

One of the most distinctive features of the phyllite is the crumpled nature of the foliation and the presence in some places of tight isoclinal folds, which have amplitudes ranging from a few mm to several cm, and smalller less conspicuous crenulations. In some places the phyllite shows compositional layers of chlorite and quartz-feldspar which vary from 1 cm to 10 cm in thickness.

Petrography

Thin section studies indicate that the Stuart Fork phyllites consist of the following minerals: abundant angular and coarse quartz grains which exhibit undulatory extinction, distinct pleochroic crystals of epidote, carlsbad twinned albite, untwinned orthoclase, and pleochroic green flakes of chlorite which commonly appear as fibrous curved trains bending around quartz and feldspar grains (Figure 10).

Accessory minerals include elongate and bent grains of magnetite, isolated calcite crystals, flakes of muscovite and scattered

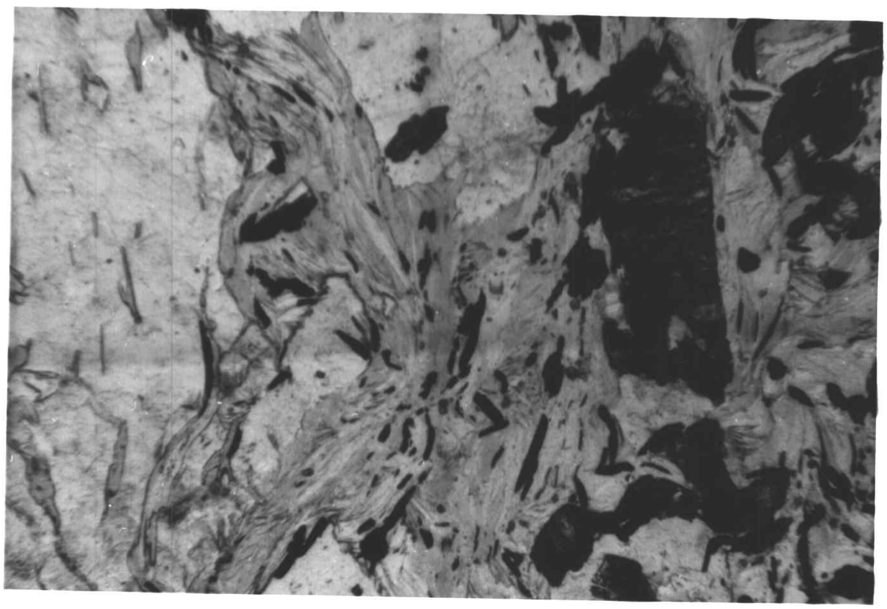

Figure 10. Thin section photo of the phyllite showing mineral constituents, texture, and bent trains of chlorite. (magnification 100 X), (Locality T-1)

grains of hematite. The percentages of these minerals appears in Table 9,

The significant lack of muscovite and scarcity of orthoclase would seem to indicate that very little potassium was present in the original sediment before metamorphism occurred.

The above petrography indicates that the phyllite is the result of metamorphism of a mixture of clay minerals including chlorite and some silt size quartz and feldspar clastics.

The phyllite contains the mineral assemblage quartz, albite, epidote, and chlorite, an assemblage which is very typical of the Greenschist Facies of metamorphism.

Structure and Thickness

The phyllites which are the result of low grade, regional metamorphism occur above an undulating thrust surface known as the Mallethead Thrust, whose character and structure is discussed on page 63.

The nature of the distribution of the phyllite makes it impossible to give any accurate estimation of its thickness. The internal structure of the phyllite was not studied in the course of this investigation.

Table 9. Modal analysis (600 points) of Stuart Fork phyllites

Constituent	T-1 (percent)	T-21 (percent)
Quartz	52	60
Chlorite	34	34
Epidote	9	3
Opaques	2	1
Plagoclase	3	2
Orthoclase	Tr	Tr

Age

The age of the phyllites is unknown and this unit is simply considered as pre-Cretaceous.

Intrusives

Hydrothermal Quartzite

Distribution

Some massive reddish brown quartzites crop out in Horseshoe Gulch, but nowhere else.

Although sometimes seen as massive, bold, resistant outcrops, this unit is commonly found intruded into the Horseshoe Gulch Limestone fault blocks. In the field it was impossible to determine whether the quartzite was of sedimentary or hydrothermal origin.

Lithology

The weathered surface color of this unit is reddish brown. The fresh surface color is pinkish white.

Petrography

Thin section studies indicate that the quartzite is of hydrothermal origin because of the presence of abundant liquid inclusions in the quartz crystals and the unstrained character of these crystals. The interlocking texture of the crystals (Figure 11) also suggests a hydrothermal origin.

Age

The age of this unit is unknown. It is considered as pre-Cretaceous(?).

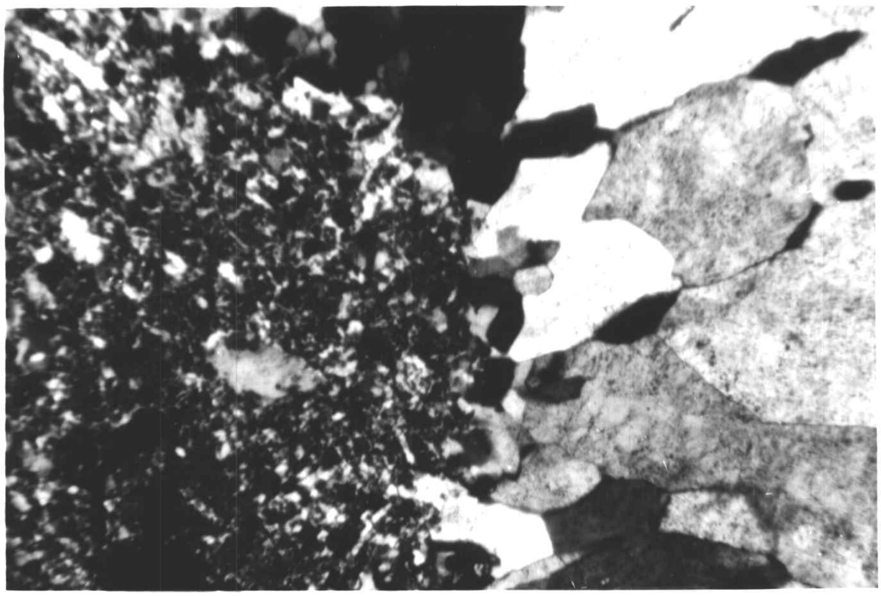

Figure 11. Quartzite showing hydrothermal texture. (magnification 100 X) (Locality T-42)

DISCUSSION OF THE MERIT OF RETAINING THE FORMATION NAME DUZEL

The Duzel Formation was first named by Wells et al. (1959 p. 645). They refer to a sequence of "gray-green phyllitic greywacke which forms the characteristic and predominant country rock in most of the area. . ." between Shasta and Scott valleys. The type locality is the drainage basin of Moffet Creek, but because the name Moffet was pre-empted they proposed the name Duzel Formation for the phyllitic sequence, after Duzel Creek, a tributary of Moffet Creek.

Wells et al. (1959) also observed limestone and associated chert beds within the phyllite and noted specifically that "interstatification of the limestone beds with phyllitic greywackes is exhibited in Horseshoe Gulch, (and) a mile to the south in Trail Gulch . . .". They specifically (1959, p. 645) included the limestones found at Duzel and Facey Rocks as being part of their Duzel Formation.

In summary, all of the units I have mapped in and around Horseshoe Gulch belong to the Duzel Formation as proposed by Wells et al. (1959). This would possibly be acceptable if the phyllites of the upper plate were not possibly of different age and thrust over the lower plate limestones and clastics found in Horseshoe Gulch. My mapping has shown the geology to be much more complex than pictured earlier.

Churkin and Langenheim (1960, p. 258) in mapping the Payton Ranch Area near Gazelle, California considered the Duzel Formation to consist of "phyllite and chlorite-muscovite semischist" thrust over unmetamorphosed Silurian strata which they assigned to the Gazelle Formation of Wells et al. In other words, Churkin and Langenheim's Duzel Formation is restricted to upper plate metamorphic rocks. Wells et al. did not recognize the presence of thrust faults in this region.

Romey (1965, p. 933) used the term Duzel Formation for three unmetamorphosed sedimentary rock type members namely; the Callahan Chert Member, a wacke mudstone member, and a quartzite member. He assigned his phyllitic rocks (which I have observed and describe as being very similar to Wells' Duzel phyllite, (p. 50) to the Stuart Fork Formation. In other words Romey's Duzel Formation is different from Wells' Duzel Formation because it consists exclusively of lower plate unmetamorphosed strata.

Because of the confusion which results from the above cited different usages of the term Duzel Formation, I propose that the term Duzel Formation be dropped completely.

My mapping has shown that two rock sequences (referred to as upper and lower plates) are present in and surrounding Horseshoe and McConaughy Gulches. Using the geologic mapping of 1970 as a basis the following terminology is proposed to clarify the situation.

Romey's term Stuart Fork Formation is used for the upper plate metamorphic "phyllites and mica-schists" which occur in this region. The lower plate is made up of the Gazelle Formation of Wells et al. (1959), the Horseshoe Gulch Limestone Formation of Horseshoe Gulch and the various other unnamed, unmetamorphosed rock units found in and around Horseshoe Gulch.

STRUCTURE

Faulting

Two types of faulting are found in the Horseshoe Gulch area. In and around Horseshoe Gulch one can discriminate local fault contacts between the different lithologic units of the lower plate. Surrounding these faulted units is a prominent regional thrust fault which separates the upper and lower plate lithologies. This regional thrust fault is a SW continuation of the Mallethead Thrust (Churkin 1960, p. 271).

Faults in the Lower Plate

Nowhere in the area has the mapping shown any sedimentary contacts to exist between the units of the lower plate. All of the units which compose the lower plate, including the massive limestone blocks, are in fault contact with the adjacent units.

The fault contact which separates the Unnamed Arkose from the Unnamed Shales and Feldspathic Wackes is not everywhere exposed in the area, but where visible a fault breccia 5 to 15 feet in width is present. This fault has a trend which varies from N 20° W to N 70° E and it extends for 4 miles from Trail Gulch to the head of McConaughy Gulch. The strike of the units on either side of this fault remain nearly the same throughout the area.

In going from Trail Gulch to Facey Rock one finds an abrupt change in lithology. The north-south trending lower plate units of Horseshoe and Trail Gulches terminate on the south side of Trail Gulch where instead one finds a calcareous siltstone which extends to and around Facey Rock. Therefore it is concluded that the Unnamed Calcareous Siltstone surrounding the Facey Rock Limestone block is separated from the lower plate units in Trail and Horseshoe Gulch by a fault trending N 50° W to N 80° W., which has been mapped very approximately.

All of the massive lower plate Upper Ordovician and Silurian(?) limestone blocks found in the area, whether fossiliferous or not, have been faulted into the surrounding units by vertical or nearly vertical movements (Figure 12). Commonly a fault breccia ranging from 1 to 10 feet in width can be seen between these limestone blocks and the surrounding rock units. The fault dips range from 60° to 90°. It appears that rotation has affected some of these massive limestone blocks because not all of the blocks are aligned in the same direction.

The lower plate limestone blocks which have been caught in the upper plate, and which now lie imbedded in the phyllites, are also surrounded by faults on all sides.

The Folded Mallethead Thrust

The Mallethead Thrust occurs between the Scott River and

Figure 12. View looking north in Trail Gulch illustrating the nature and characteristic occurrence of the massive fault blocks of limestone found in the thesis area. (Locality Z-9)

Shasta Valleys, Siskiyou County, California, and was named by Churkin (1960) from its occurrence at Mallethead Rock, China Mountain Quadrangle. The trace of the thrust has been mapped by Churkin, Romey, Boucot et al. and myself in parts of the Etna, Fort Jones, Yreka, and China Mountain Quadrangles. The thrust extends north-south from near the town of Yreka to the town of Callahan. It is the largest and most prominent structural feature of the area and it brings upper plate unfossiliferous, chlorite grade, metamorphic rocks over lower plate fossiliferous Lower Paleozoic limestones plus unfossiliferous sandstones, shales, mudstones, and other terrigenous clastic rocks.

The upper plate lithology is primarily dark green, chlorite, mica and quartz rich phyllite which commonly exhibits a crumpled foliation, tight isoclinal folds, and less conspicuous crenulations.

The lower plate contains massive Ashgill and Silurian age fossiliferous limestone blocks, with dimensions measured in hundreds of yards. These limestone blocks have been faulted by vertical movements into surrounding arkosic wackes and feldspathic wackes. Because the limestone blocks have a tectonic origin, no continuous limestone sequence is found in the area and mapping has shown that the distribution of the massive blocks is chaotic and random. Essentially, the exposed lower plate rocks are in the lower part of a highly disturbed fault zone. The trace of the thrust is very sinuous and irregular with at least one window occurring to the north at Duzel Rock, Fort Jones Quadrangle.

In the Horseshoe Gulch area the fault zone is approximately 1 mile wide. The overlying phyllites have been eroded from a large part of the area and mapping shows that the lower plate is now bounded on three sides by metamorphic rocks.

The phyllites close to the western contact of the Mallethead Thrust with the lower plate sedimentary rocks in McConaughy Gulch are characterized by numerous, small, badly crushed and sheared limestone blocks which have been caught up in the thrust fault and which now lie imbedded in the upper plate phyllites. These limestone blocks are not metamorphosed in any way and it is concluded that they originate from and were originally part of the lower plate. Mapping has shown that the limestone blocks imbedded in the phyllites occur at a maximum horizontal distance of 2500 feet from the western exposures of the Mallethead Thrust in McConaughy Gulch.

The Mallethead Thrust has been folded into a series of broad, north-south, plunging anticlines and synclines between the Scott River and Shasta Valleys of Siskiyou County. As a result the surface between the upper and lower plates is generally undulating in character. In order to illustrate the character and the undulations of the Mallethead Thrust surface, two structure contour maps were made. In both of the structure maps the intersection of the thrust fault contact and the topography were used as control points for subsequent contouring of the thrust surface. The first structure contour map (Plate 2) illustrates the undulations of the Mallethead Thrust on a regional scale. My data, work done by Boucot and others in 1963, Churkin's mapping, and inferences from Romey's mapping were used to outline the trace of the thrust fault from the west side of the Scott River Valley to the Gazelle area.

The second structure contour map (Plate 3) is of my mapped area only. This structure map indicates the presence of an anticline. The average dips for the thrust contact between the upper and lower plates in this area vary from 20° to 50°. The variation in dip is the result of folding. Numerous cross sections were constructed across this map and it was found that the limestone blocks presently imbedded in the phyllite on the western contact of the Mallethead Thrust in McConaughy Gulch have been vertically faulted through the upper plate metamorphic rocks to a maximum vertical distance of 1200 feet from the thrust plane.

The age of the thrusting is not known precisely. In the mapped area it must have occurred later than the youngest fossiliferous, Late Silurian (Ludlow) limestone rocks present. Thus the Mallethead Thrust is at least post-Upper Silurian (Ludlow) in the Horseshoe Gulch area. Mapping has shown Lower Devonian limestones to occur relatively nearby and unmetamorphosed Permo-Carboniferous as well as Triassic rocks have been found elsewhere in the Klamath Mountains. With this evidence an age ranging from Lower Devonian to upper Cretaceous can be assigned to the Mallethead Thrust. The age limits placed on time of folding are similar.

ECONOMIC GEOLOGY

No economic mineral deposits were found to occur in the thesis area. Two abandoned trenches and tailings were found in the phyllites and the hydrothermal quartzites, but these were not studied. Some of the limestone blocks in the area have at one time been used for agricultural lime.

Although no mineralization occurs in the thesis area the Scott River Valley has been extensively dredged for gold.

BIBLIOGRAPHY

Billings, M. P., 1954, Structural Geology; Prentice-Hall, Inc., Englewood Cliffs, 514 p.

Berry, L. G., and Mason, Brian, 1959, Mineralogy: Freeman, San Francisco, 630 p.

Berry, W. B. N., and Boucot, A. J., 1970, Correlation of the North American Silurian Rocks; Geol. Soc. of America, Special Paper 102, 289 p.

Churkin, Michael, Jr., and Langenheim, R. L., Jr., 1960, Silurian strata of the Klamath Mountains, California. Am. Jour. Sci., v. 258, p. 258-273.

Compton, R. R., 1962, Manual of Field Geology; John Wiley and Sons Inc., New York, 378 p.

Davis, G. A., Holdaway, M. J., Lipman, P. W., and Romey, W. D., 1962, Structure, Metamorphism, and Plutonism in the South-Central Klamath Mountains, California: Geol. Soc. America Bull., v. 76, p. 933-966.

Folk, R. L., 1968, Petrology of Sedimentary Rocks; Hemphill's, Austin, Texas, 170 p.

Ham, W. F., 1962, Classification of carbonate rocks, A symposium; Am. Assoc. of Petrol. Geol. Mem. 1, 279 p.

Irwin, W. P., 1960, Geologic reconnaissance of the northern coast ranges and Klamath Mountains, California: California Div. Mines Bull. 179, 80 p.

Irwin, W. P., 1966, Geology of the Klamath Mountains province, in: Geology of northern California, ed. by E. H. Bailey. Calif. Div. Mines and Geol. Bull. 190, p. 19-38.

Johnson, J. H., 1951, An Introduction to the Study of Organic Limestones; Colorado School of Mines Quarterly, v. 46 #2, 185 p.

Johnson, J. H., Konishi, K., and Rezak, R., 1959, Studies of Silurian (Gotlandian) Algae; Quarterly of the Colorado School of Mines, v. 54 #1, p. 135-158.

Kerr, P. F., 1959, Optical Mineralogy; McGraw-Hill, New York, 442 p.

Klug, H. P., and Alexander, L. E., 1954, X-Ray diffraction procedures for polycrystalline and amorphous materials: John Wiley and Sons Inc., New York 716 p.

Lahee, F. H., 1961, Field Geology, McGraw Hill, New York, 6th edition, 926 p.

Majewske, O. P., 1969, Recognition of Invertebrate Fossil Fragments in Rocks and Thin Sections; Internat. Sedimentary Petrographical Series v. 13, 101 p.

Moorhouse, W. W., 1959, The Study of Rocks in Thin Section: Harper and Row, New York, 514 p.

Pettijohn, F. J., 1957. Sedimentary Rocks: Harper and Row Inc., New York, 2nd edition, 718 p.

Pray, L. C., and Murray, R. C., 1965. Dolomitization and limestone diagenesis, a symposium; soc. of Econ. Paleont. and Mineral., Special Pub. #13, 180 p.

Strand, R. G., 1963, Index to geologic mapping used in the compilation of the Weed Sheet; California Div. Mines and Geol.

Turner, F. J., and Verhoogen, J. O., 1960, Igneous and metamorphic petrology: McGraw-Hill, New York, 694 p.

Wells, Walker, G. W., and Merriam, C. W., 1959, Upper Ordovician(?) and Upper Silurian formations of the northern Klamath Mountains, California: Geol. Soc. America Bull., v. 70, p. 645-649.

Williams, H., Turner, F. J., and Gilbert, C. M., 1953, Petrography: Freeman, San Francisco, 406 p.

APPENDICES

APPENDIX I

Fossil Localities and Faunal Lists

A number of the limestone blocks found in the thesis area yielded megafossils and/or microfossils.

Identification and age dates were provided for the brachiopods by A. Boucot, and J. G. Johnson, the corals were examined by A. Wright and the conodonts were studied by C. Rexroad.

Fossil Locality Z-1; Horseshoe Gulch Limestone Unit

Location S. E. 1/4 of the S. E. 1/4 of Section 4 of the N. E. 1/4 of Etna Quadrangle. R8W, T41 N.

Brachiopods

Anoptambonites sp.

triplesiid sp.

trimerellid sp.

Brevilamula sp.

Hesperorthis? sp.

indet. orthid

indet. leptaenid

indet. brachs

indet. plectambonitid

indet. dalmanellid

Corals

Grewingkia sp.

Proheliolites? (or probably *Propora*)

Propora? sp.

Quepora? sp.

Catenipora sp. (probably Sp. B small celled variety)

<u>Conodonts</u>

- blank (none found in residues)

<u>Other</u>

bivalves

gastropods

tetracorals

indet. tabulates

indet. fragments

<u>Age</u>

The presence of the coral *Grewingkia* along with the brachiopods *Anoptambonites* and *Brevilamula* fixes the age fairly precisely as Late Ordovician. The general aspect of the fauna is similar to other fossil localities of Ashgill age.

Fossil Locality Z-5, Unnamed Limestone Unit

Location: N 1/2 of section 26 of NW 1/4 of China Mountain Quadrangle R8W, T42N.

Brachiopods

none found

Corals

none found

Conodonts

Panderodus simplex

Age

The range of *Panderodus simplex* (Branson and Mehl) according to Rexroad (written communication, 1971) is from the Ordovician through the Silurian. Because this unit is lithologically similar to the known Silurian age unit in the area, this unit is considered as Silurian(?).

Fossil Locality Z-9, Unnamed Limestone Unit

Location: N 1/2 of section 16 of the NE 1/4 of Etna Quadrangle, R8W, T41N.

Brachiopods

none found

Corals

none found

Conodonts

Panderodus sp. single specimen that was not identifiable as to species, Rexroad (written communication, 1971)

Age

Insufficient data to give any precise date.

Fossil Locality Z-12, Horseshoe Gulch Limestone Unit

Location: NW 1/4 of the SW 1/4 of section 10 of the NE 1/4 of Etna Quadrangle R8W, T41N.

Brachiopods

Dicaelosia sp. (long, Ashgill type, cf. *D. jonesridgensis*)

Corals

none found

Conodonts

none found

Other

indet. object

Age

The presence of *Dicaelosia* sp. cf. *D. jonesridgensis* indicates an Ashgill age for this limestone block.

Fossil Locality Z-13, Horseshoe Gulch Limestone Unit

Location: N 1/2 of section 3 of the NE 1/4 of Etna Quadrangle, R8W, T 41 N (collected by Zdanowicz, 1970).

Brachiopods

Anoptambonites sp.

Hesperorthis? sp.

Spirigerina sp.

Brevilamula sp.

orthotetacean

indet. orthid sp.

indet. brachiopod sp. A

indet. brachiopod sp. B

Corals

Grewingkia

Catenipora sp. A

Catenipora sp. B

Propora sp. A

Palaeophyllum?

Quepora?

Conodonts

none found

Other

indet. algae

indet. fragments

Location: N 1/2 of section 3 of the NE 1/4 of Etna Quadrangle

R8W, T41N (collected by Boucot, 1963).

Brachiopods

Plaesiomys sp.

Glypterina sp.

Spirigerina sp.

Dayia-form?

Corals

none found

Conodonts

none found

Age

The presence of the coral *Grewingkia* along with the brachiopods *Anoptambonites*, *Glypterina*, *Spirigerina*, and *Brevilamula*, indicates a Late Ordovician (Ashgill) age for this fauna.

Fossil Locality Z-18, Horseshoe Gulch Limestone Unit

Location: W 1/2 of section 3 of the NE 1/4 of Etna Quadrangle, R8W, T41N.

Brachipods

Spirigerina sp.

Brevilamula sp.

indet. orthid

indet. brachiopods

Corals

none found

Conodonts

none found

Other

algae

indet. objects

Age

The presence of the brachiopods Spirigerina, and Brevilamula indicate an Ashgill age for this limestone block because these genera have been found at other Horseshoe Gulch Limestone localities which have yielded brachiopods like Anoptambonites.

Fossil Locality Z-19, Unnamed Limestone Unit

Location: N 1/2 of section 3 of the NE 1/4 of Etna Quadrangle, R8W, T41N.

The only fossils extracted from this locality were unidentifiable gastropods. No age determination can be made.

Fossil Locality Z-22, Unnamed Silurian Limestone Unit

Location: N 1/2 of section 3 of the NE 1/4 of Etna Quadrangle, R8W, T41N.

Brachiopods

none found

Corals

Entelophyllum?, possibly a disphyllid

Phaulactis?

Battersbyia? (*Fletcheria*?)

squamate favositid

thamnoporoids

Conodonts

Spathognathodus primus (Branson & Mehl)

Neoprioniodus multiformis Walliser (of the holotype form)

Hindeodella equidentata Rhodes (2)

Trichonodella symmetrica (Branson & Mehl)

Panderodus simplex (Branson & Mehl) (2)

Panderodus unicostatus (Branson & Mehl)

Panderodus gracilis (Branson & Mehl)

Age

On the basis of corals and conodonts this fauna is dated as Late Silurian. A. Wright (written communication, 1971) feels that this fauna is "certainly post-Llandovery, if Battersbyia is really present this could be a Devonian fauna (not earliest Devonian but Emsian or younger). However, if this fossil is Fletcheria, a Silurian age is indicated. Rexroad in written communication (1971) with the author indicated that "Published information would indicate a siluricus Zone age because Spathognathodus primus is shown by Walliser to be no older than that zone and Neoprioniodus multiformis to no younger. S. primus however, almost certainly comes from appreciably below the siluricus-Zone, and the range of N. multiformis is being extended. I should say that all the species are consistent with a siluricus Zone age and . . . one of the specimens of Spathognathodus primus in the last run was of a late form that Walliser records from the crispus-latialatus and eosteinhornensis Zones. It is far more advanced certainly that S. primus from the Bainbridge where it is associated with conodonts of the siluricus-Zone. To me this is good evidence for a very late Ludlow or even a Pridoli age assignment for Z-22."

In summary on the basis of the fauna found at this locality, it is assigned a very late Ludlow age.

Fossil Locality Z-23, Unnamed Silurian Limestone Unit

Location: N 1/2 of section 3 of the NE 1/4 of Etna Quadrangle, R8W, T41N.

Brachiopods

none found

Corals

Tryplasma sp.

Dalmanophyllum? or *Neobrachyelasma*? sp.

cystimorph

Conodonts

none found

Age

According to A. Wright the corals indicate a probable Wenlockian age.

Samples of the following localities were processed by Carl Rexroad but in every case results were negative.

Fossil localities: Z-1, Z-4, Z-10, Z-12, Z-13, Z-15, Z-23, and T-15.

APPENDIX II

Insoluble Limestone Residue Results

Table 10. Insoluble limestone residue percentages for Horseshoe Gulch area limestone units

	Locality	Original weight of sample (gms)	Insoluble residue percentage
Horseshoe Gulch Limestone	Z-1	88.70	12.23
	Z-13	216.78	15.10
	Z-12	139.95	4.08
	Z-18	240.45	9.09
Unnamed Silurian? Limestone	Z-4	236.16	3.80
	Z-5	175.63	12.61
	Z-6	142.50	2.79
Facey Rock Limestone	Z-14	197.85	0.80
	Z-16	191.85	2.79
Silurian Limestone	Z-22	193.40	11.11
	Z-23	150.49	9.81

Explanation of the data leads to no viable conclusions.