Sedimentology and Depositional Setting of the Miocene Marnoso-Arenacea Flysch, Marche Region, Italy

An honors thesis submitted to the faculty of
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ABSTRACT

The Coldigioco-Castellaro basin is the Easternmost basin in a series of basins and adjacent topographic highs formed during the Early Miocene epoch by compression that produced the Italian Northern Apennines. Part of the Marnoso-Arenacea flysch, a sequence of sandstone, conglomerate, and mudstone, accumulated in this late stage basin bounded by two, synsedimentary, thrust-produced anticlines. This study examines the influence of the anticlines on flysch sedimentation in the basin.

INTRODUCTION

The Coldigioco-Castellaro basin is a small basin located within the Italian Northern Apennines about 45 km southwest of Ancona, Italy. It is the Easternmost basin (closest to the Adriatic coast) in a series of hills and basins trending northeast-southwest, produced by folding and thrusting during the Miocene epoch. Coldigioco, a small village in this basin, is home to the Osservatorio Geologico di Coldigioco, the base of study during time spent in Italy.

The objectives of this study were to determine the provenance of the sandstones and conglomerates of the Marnoso-Arenacea formation in the Coldigioco-Castellaro basin, reconstruct a depositional environment, and evaluate the effect the growth of the Cingoli Anticline had on the sedimentation in this basin.

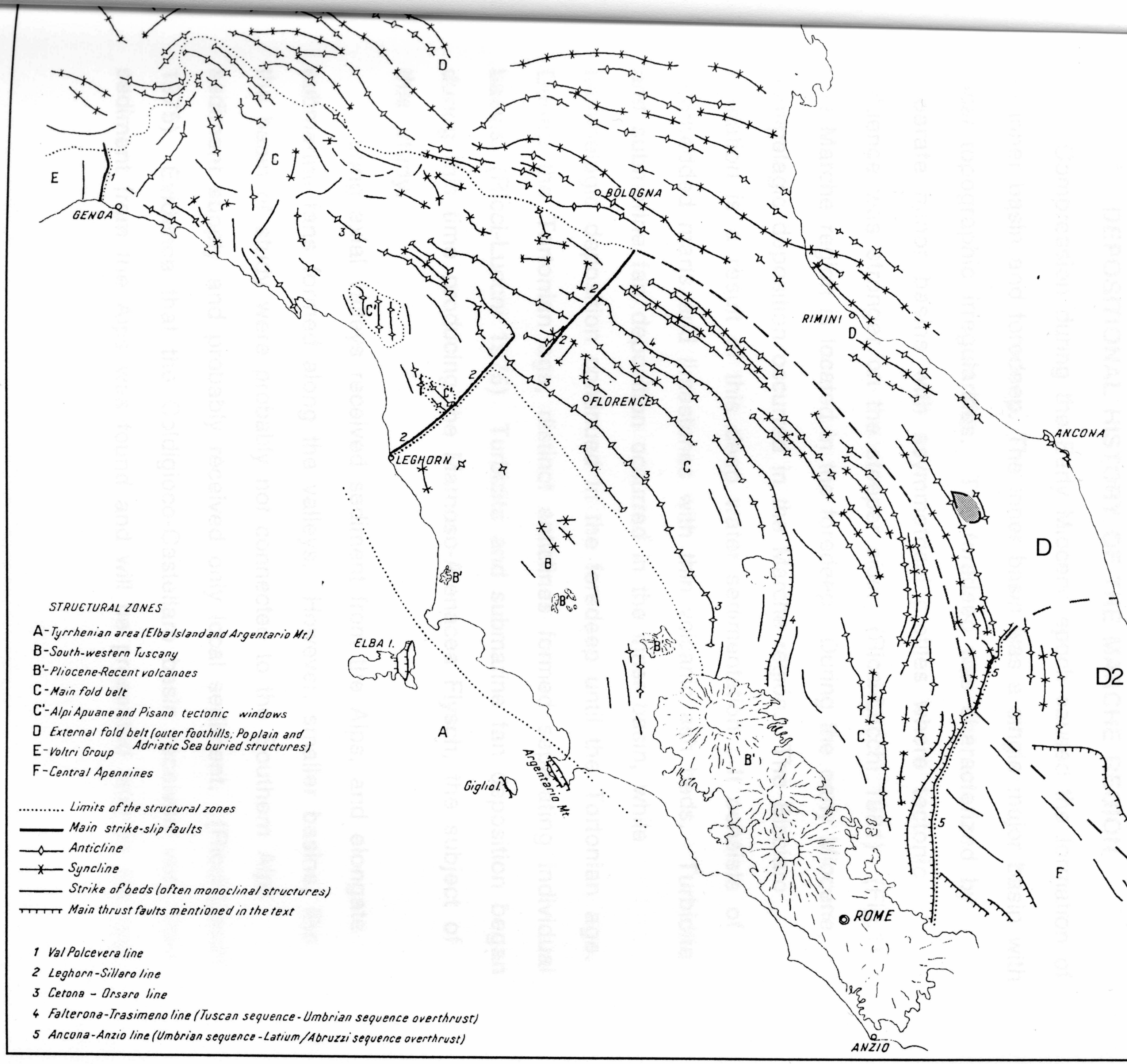
STRUCTURAL HISTORY OF THE NORTHERN APENNINES

The complex structural history of the Italian peninsula reflects the complexities of plate tectonics across the Mediterranean region. Nevertheless, the structure of the Northern Apennines is fairly well understood. The Italian peninsula was probably attached to southeast Europe until the early Jurassic, when a small ocean basin (the Ligurian Ocean) began to form as rifting rotated what is now Italy away from southeast Europe. (Bice et al, 1990) This early Jurassic rifting produced a series of horsts and grabens. Continuous deposition of pelagic limestone accumulated in the basins until the Miocene epoch, while condensed sequences were deposited on structural highs.

By the early Miocene epoch, the sea floor was relatively even topographically, when the area experienced renewed tectonism. Compression of the area began during the early Miocene epoch in the southwest, and moved as a wave toward the northeast. This area remains active; the compressional front is located off shore in the Adriatic Sea. Compression generated a series of thrusts that propagated across the peninsula (see Fig. 1) As each individual thrust became inactive, a new thrust developed to the Northeast, carrying the older inactive thrust along on it. Thrusts therefore become younger toward the Northeast.

Figure 1: Structural Map of the Northern Apennines

Structural zone C coincides with inner basin. Dashed line shows boundary between inner basin and foredeep. Structural zone D coincides with foredeep, while D2 coincides with southern foredeep. Shaded area shows the Coldigioco-Castellaro basin. (map modified from Abbate et al, 1970)



DEPOSITIONAL HISTORY OF THE MARCHE REGION

Compression during the Early Miocene epoch caused the formation of an inner basin and foredeep. The inner basin was a single major basin with local topographic irregularities. The foredeep was characterized by separate minor basins with asymmetrical profiles where tectonic influence was stronger on the steeper side. (Ricci-Lucchi 1981) (Fig.1) The Marche region is located in the foredeep. During the early Miocene, hemipelagic deposition occurred in the Marche region. The Bisciaro formation is a result of this deep water sedimentation. It consists of interbedded marls and limestones with thin volcanic ash beds. Turbidite and submarine fan deposition occurred in the inner basin, while hemipelagic deposition continued in the foredeep until the Tortonian age. During the Tortonian age, distinct anticlines formed separating individual basins. (Ricci-Lucchi 1975) Turbidite and submarine fan deposition began during this time producing the Marnoso-Arenacea Flysch, the subject of this study.

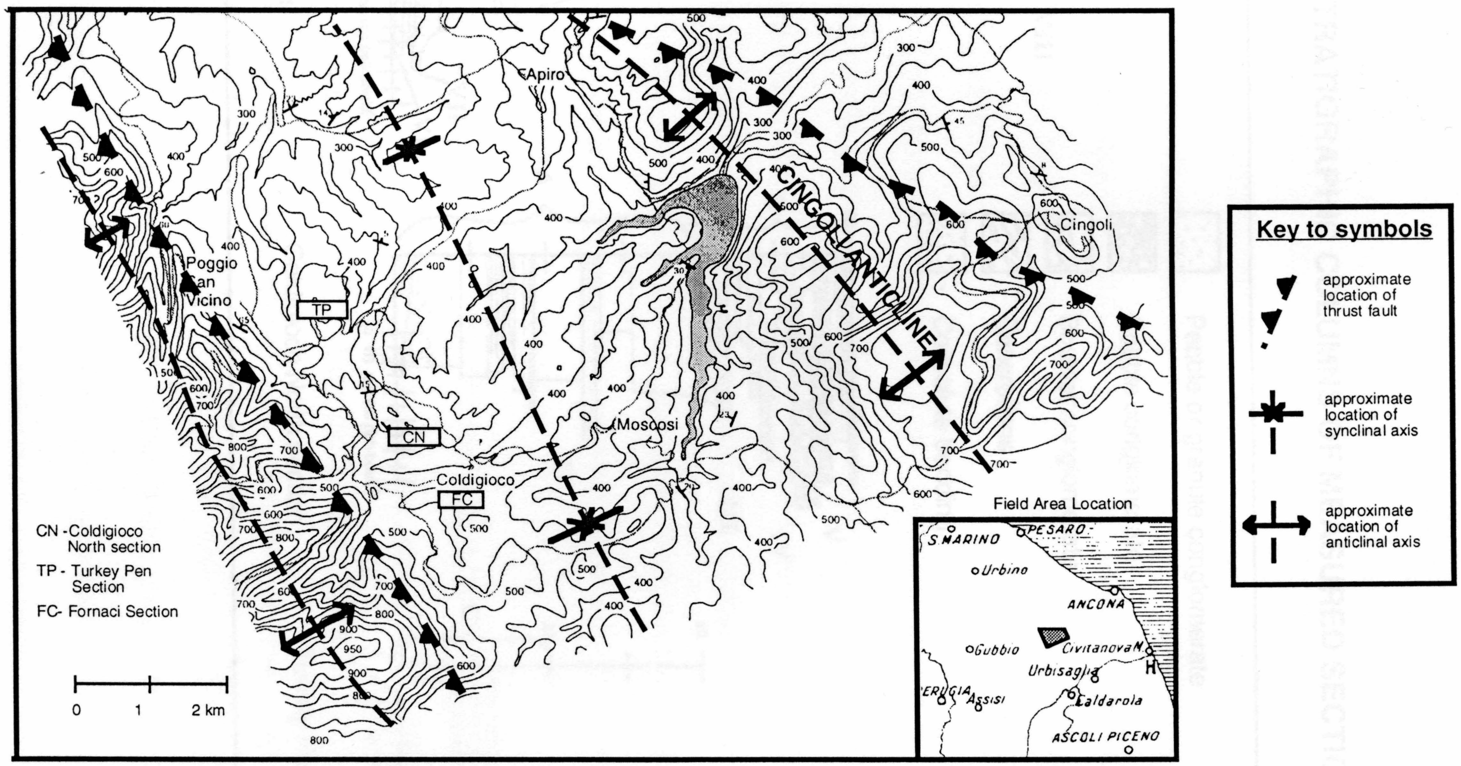
Long axial valleys received sediment from the Alps, and elongate submarine fans formed along the valleys. However, smaller basins, like the basin of study were probably not connected to the Southern Alps sediment supply and probably received only local sediment. (Ricci-Lucchi 1975) Evidence that the Coldigioco-Castellaro basin received very little sediment from the Alps was found and will be presented later in the text.

METHODS

Three sites (Figure 2) were selected in order to produce detailed stratigraphic measurement emphasizing composition, texture, and sedimentary structures; using these attributes four distinct facies can be identified.

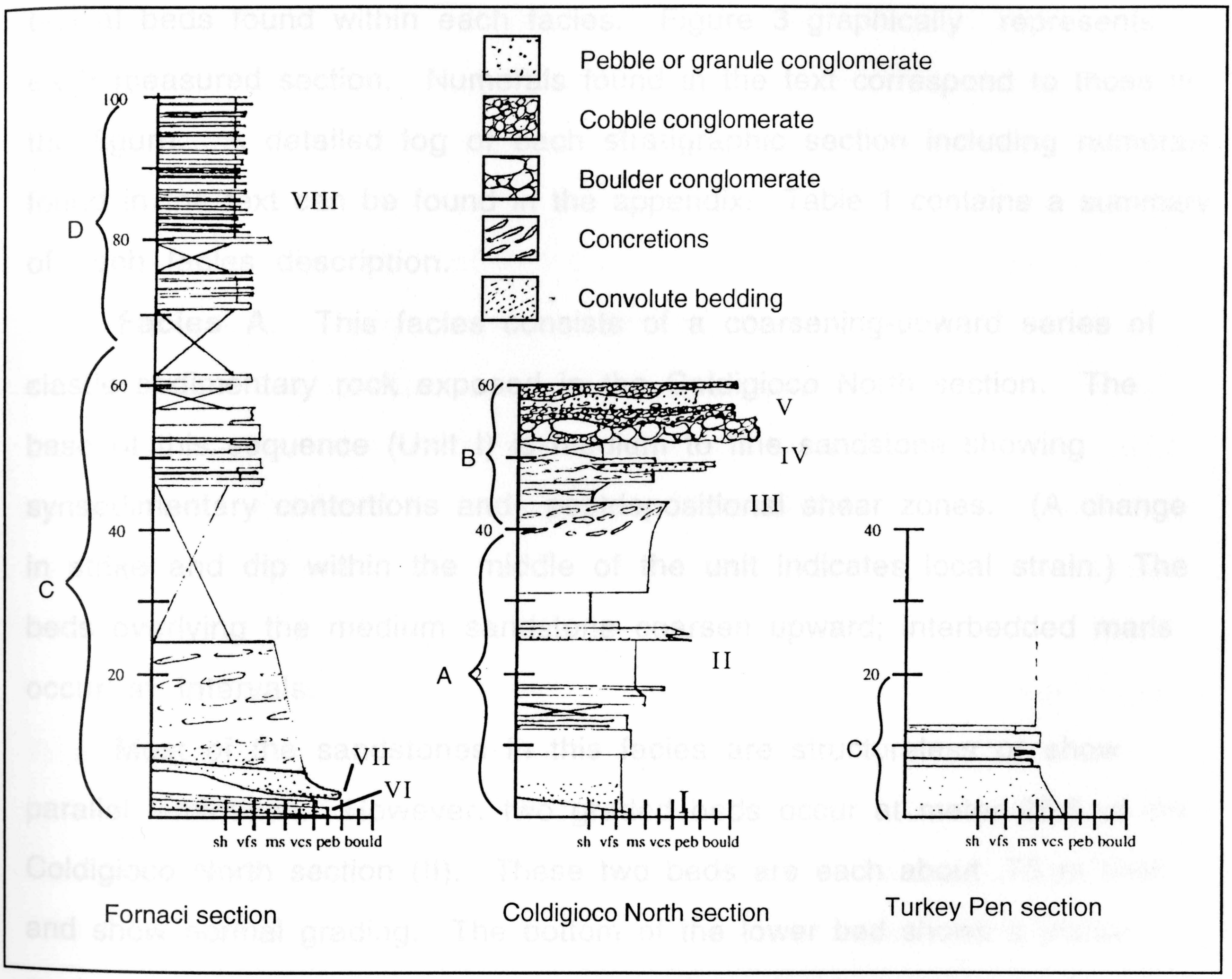
Eleven thin sections sampled at these localities were point-counted to determine compositional and textural attributes from which provenance and transporting agents can be inferred. Compositional analysis concentrated on the identification of rock fragments that might differentiate a metamorphic Alpine and a local source. Textural attributes for conglomerates at the top of the Coldigioco North section were analyzed directly at the outcrop. Petrographic data confirms the viability of the four facies defined on the basis of characteristics observed in the field.

Figure 2: LOCATION OF STRATIGRAPHIC SECTIONS AND GENERALIZED STRUCTURAL MAP OF THE BASIN



Base map tirelessly digitized by brandon gillis

Figure 3: STRATIGRAPHIC COLUMNS OF MEASURED SECTIONS



FACIES DESCRIPTIONS

Four distinct facies occur in the basin. Each facies consists of a series of beds of distinct composition and sedimentary structures, related by similar transporting agents and depositional conditions. Units discussed provide information about the processes at work and represent typical beds found within each facies. Figure 3 graphically represents each measured section. Numerals found in the text correspond to those in the figure. A detailed log of each stratigraphic section including numerals found in the text can be found in the appendix. Table 1 contains a summary of each facies description.

Facies A. This facies consists of a coarsening-upward series of clastic sedimentary rock exposed in the Coldigioco North section. The base of this sequence (Unit I) is medium to fine sandstone showing synsedimentary contortions and postdepositional shear zones. (A change in strike and dip within the middle of the unit indicates local strain.) The beds overlying the medium sandstone coarsen upward; interbedded marls occur at intervals.

Most of the sandstones in this facies are structureless or show parallel lamination. However, two graded beds occur at meter 25.5 of the Coldigioco North section (II). These two beds are each about .75 m thick and show normal grading. The bottom of the lower bed shows a planar contact with the coarse sand below it, and the top bed shows an irregular contact with the lowermost graded bed. The base of each bed is a pebble/granule conglomerate containing pebbles and granules of white limestone, green and red chert, and quartz in a matrix of very coarse sandstone with abundant muscovite. This coarse material grades into a tan coarse sandstone with granules of similar composition to those in the base. The sequence repeats itself in the second bed and is overlain by a twelve centimeter thick very fine sandstone that shows ripple cross-lamination. This sequence is found only once in the Coldigioco North section. Poor exposure and extensive weathering of sections of the outcrop could mask other graded beds.

Facies B. This is a second coarsening upward sequence distinguished from facies A by lenticular bedding and very coarse conglomerates. This facies occurs in the upper part of the Coldigioco North section.

The first lenticular bed (III) occurs just below the coarse conglomerates at Coldigioco North. The conglomerate surrounding the lenticular bed is a medium to coarse, poorly cemented and poorly sorted conglomerate that contains about 5% white limestone granules and sand-size clasts of chert and flakes of mica. Concretions up to one meter long and twenty centimeters thick that occur within the unit suggest channel outlines.

The lenticular bed is thirty centimeters thick at its thickest point. Its margin is poorly defined, and the bed consists of two components. A ten centimeter thick pebble conglomerate with a very few siltstone intraclasts up to eight centimeters long, contains a matrix of coarse sand with spherical to flattened limestone pebbles that measure 3.5 cm along the long axis and forms the bottom of the bed. The second portion of the lenticular bed is pebble conglomerate up to twenty centimeters thick, also with a matrix of very coarse sandstone. Clasts of siltstone, limestone, and mudstone (up to 35 x 4 cm) occur. Above the lenticular bed, the conglomerate coarsens near the top.

The lowermost coarse conglomerate (IV) occurs just above a covered area in the section. The base of the unit is not visible. One to 1.15 meters of measurable section reveal a clast-to matrix-supported boulder conglomerate with no grading that contains white and grey limestone and marl clasts of the Miocene Bisciaro formation up to 1 x 1.3 m in size floating in a matrix of coarse sandstone and mudstone. The boulders are subangular to well-rounded with roundness generally increasing with increased clast size. The larger boulders are almost entirely limestone or marl, but some smaller boulders and cobbles consist of siltstone, mudstone, and coarse and fine sandstone. There is an irregular contact between this bed and the overlying bed where some of the larger boulders protrude from the top of the bed. Two cobble conglomerates (V) showing weak inverse grading overlie the boulder conglomerate and lie beneath a pebble conglomerate that is deeply cut by a lenticular bedded cobble conglomerate above it. The pebble conglomerate contains scattered cobbles in the first half a meter at the base. The cobble conglomerates are formed almost entirely of white limestone clasts (similar to the limestones of the Bisciaro formation) in a matrix of coarse sand.

Facies C. This is a fining-upward sequence that can be seen in the Turkey pen and Fornaci sections. It fines upward from a poorly sorted pebble-granule conglomerate to a moderately well-sorted medium sandstone. The bottom of the section at Fornaci shows this facies. The bottom 1.8 meters of measurable section at Fornaci (VI) is a cross-laminated pebble conglomerate with pebble-size clasts of mudstone near the base and limestone and chert throughout. This unit grades upward into a sixty centimeter thick very coarse sandstone conglomerate that contains 1 cm thick granule-rich layers throughout. This granule-rich unit in turn grades upward into a 20 to 170 cm thick coarse sand conglomerate that is incised by a large lenticular bedded granule conglomerate that fines into a very poorly sorted, very coarse sand conglomerate (VII). The top of the lenticular bed is defined by a half meter of poorly sorted medium sandstone with approximately 10% coarser material. The bed ranges in thickness from 1.2 to 1.5 meters. Above the lenticular bed, coarser material is concentrated into granule-rich horizontal laminae that alternate with granule-poor coarse to medium sandstone. The rest of the sequence is structureless, except it fines upward gradually over twenty-four meters. A similar vertical sequence (excluding the lenticular bed) occurs in the Turkey Pen section.

Facies D. This facies consists of interbedded ripple cross-laminated or parallel-laminated very fine sandstones and siltstones and parallel-laminated or structureless mudstones. These lithologies can be seen in the upper portion of the Fornaci section. The beds occur in sequences of two or three bed showing C-E Bouma sequences. At the bottom of most of the sequences is a ripple cross-laminated fine sandstone or siltstone. This is overlain by a parallel-laminated mudstone and structureless mudstone, though the parallel-laminated mudstone is not always present. Poor exposure characterizes this section, but in one area (VIII) a full Bouma sequence missing only the A bed was found.

Table 1: Summary of Facies Analysis

	Facies A	Facies B	Facies C	Facies D
Facies Description	Coarsening upward sequence of medium sandstones to very coarse sandstones	Coarsening upward sequence of pebble conglomerates to boulder conglomerates	Fining upward sequence of pebble conglomerates to medium sands	Fining upward sequence of thin bedded fine sandstones and mudstones
Sedimentary Structures	Some graded beds, parallel lamination, few ripple cross laminated sandstones	Lenticular bedding, weak inverse grading in some conglomerates	Lenticular bedding, parallel lamination, graded bedding	Ripple cross lamination, parallel lamination, convolute lamination
Tectonic Structures	Convolute bedding, shear planes, change in strike and dip of beds		Change in dip of beds, shear planes	
Sorting	Moderately well sorted	Poorly sorted	Poorly sorted at base to moderately well sorted at top	Moderately well to well sorted
Typical Grain Size	Medium sand	Cobble/ boulder	granule at base to medium sand at top	very fine sand to mud

TRANSPORT AGENTS AND DEPOSITIONAL SETTING

Textural analysis and field observation indicate that the facies in this basin were part of a submarine fan complex. Each facies represents a different part of the fan. However, each described facies may not be a part of the same fan, and they may be different in age. Figure 4 shows the probable location of each facies on a single fan.

Facies A. The thick sandstone beds and coarsening-upward sequence typify upper fan channel fill deposits. Thick sandstones, commonly slumped, are the main channel deposits. Convolutions at the base of the sequence may be the result of minor slumping. The graded beds are grain flows that occur in the main channel. Nilson and Abbate (1985) found thickening-upward sequences and synsedimentary slumping in the upper fan channel of the Gottero turbidite system in Italy.

Facies B. The conglomerates of this facies were deposited in the upper section of a submarine fan, perhaps in the feeder channel to the fan. The conglomerates are debris flows. Nilson (1985) describes conglomerates of the upper fan deposited in channels. These conglomerates contain clasts as big as 25 cm and are locally graded. Clasts found in the area of study are as large as 130 cm in the boulder conglomerate, and the conglomerates show weak grading if any.

Clasts have not been transported far, based on the degree of rounding seen in the large boulders and cobbles. Lenticular beds are channel deposits. Concretions in the fine conglomerate below the debris flows may trace the bottom of migrating channels. They cut the conglomerate into lenticular sections that migrate from side to side, and could be the result of a migrating channel at the head of the fan. The debris flows are the result of deposition in the large feeder channels for the fan.

Thin section analysis further strengthens the case that these are upper fan deposits. These deposits are poorly sorted and very angular, as would be expected in the portion of the fan closest to the source.

Facies C. The conglomerates and sandstones of this facies resemble channel deposits from the mid-fan suprafan lobe channels. Walker (1979) describes channelized pebbly sandstones in braided suprafan channels. As the channel fills with successive deposits, the sediments fine upward. Mid-fan channel pebbly sandstone deposits can be graded, channeled, and show horizontal lamination or various forms of cross-stratification. Mutti (1985) also describes channel fill sequences of the Hecho turbidite system in Spain. These sequences are composed of thick conglomerates and pebbly sandstones that grade into fine grained overbank deposits.

Thin sections show an increase in sorting and rounding as the unit fines upward. This trend demonstrates the filling of the channel. As the channel fills, the sediments become better sorted and rounder due to a decrease in slope. Carbonate clasts show the greatest change in degree of rounding. At the base of the channel, these clasts are subangular but become progressively more rounded toward the top of the deposit. Quartz grains grade from very angular at the base of the deposit to subangular at the top.

Facies D. These deposits represent the distal portion of the fan, where slower moving turbidite currents deposited fine sands and muds in C-E Bouma sequences. Large numbers of these C-E Bouma sequences indicate that this facies was deposited distally. However, there is an alternative explanation for these fine sands and muds. Inner fan levees also consist of mud and silt. Where currents are strong enough, rippling of the silt produces C-E turbidites much like the ones produced in the distal portion of the fan. Since this deposit is found above a channelized mid-fan sandstone, the silts and muds could be levee deposits, but the abundance of fine sand suggests a more distal environment, because levee deposits usually only contain the finest particles. (Walker, 1979)

The abundance of carbonate clasts identified in the sandstones and debris flows suggests that the sediments were locally derived, but lack of directional structure indicators precludes inferences on flow direction. Changes in dip, shear planes, and contortions in the sediments suggest that the growing anticline affected deposition. Changes in thickness of beds due to tilting during deposition probably occur, but poor exposure does not allow lateral changes in thickness to be detected. The growth of the anticline may have influenced deposition, but there is little evidence to support such a conclusion.

Figure 4: GENERAL DIAGRAM OF A SUBMARINE FAN SHOWING LOCATIONS OF DESCRIBED FACIES

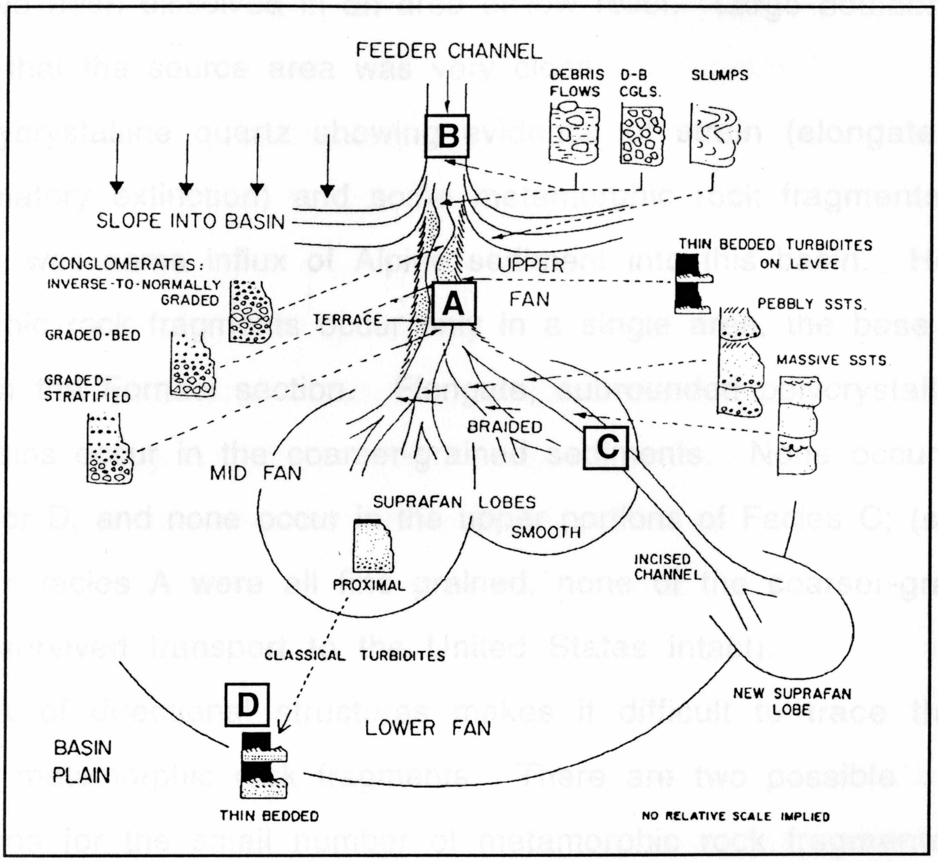


Diagram modified from Walker 1979

PROVENANCE

Sandstone composition suggests that these deposits accumulated adjacent to an area of high relief. Abundant carbonate clasts (up to 43% in one sample) with mean roundness ranging from angular to subrounded indicate that the source area was relatively high. Carbonate source rocks would have been dissolved in an area of low relief. Large boulder size suggests that the source area was very close.

Polycrystalline quartz showing evidence of strain (elongate grains and undulatory extinction) and some metamorphic rock fragments indicate that there was some influx of Alpine sediment into this basin. However, metamorphic rock fragments occur only in a single area, the base of the channel in the Fornaci section. Elongate, subrounded polycrystalline quartz grains occur in the coarser-grained sediments. None occur in Facies A or D, and none occur in the upper portions of Facies C; (samples taken from facies A were all fine grained, none of the coarser-grained samples survived transport to the United States intact).

Lack of directional structures makes it difficult to trace the likely source of metamorphic rock fragments. There are two possible explanations for the small number of metamorphic rock fragments.

(1) The Coldigioco-Castellaro basin may have been connected to a larger fan complex whose source was located in the Southern Alps. Ricci-Lucchi, (1975) described a sand belt reaching from the Southern Alps into the Marche region that was formed by connecting fan complexes along the foredeep. This system may have produced an influx of metamorphic sediment into the basin at certain times in the development of the basin. However, the small amount of metamorphic sediment and large amount of local clastic sediment found together in these samples is perplexing. If

there was an influx of Alpine sediment into the basin, one would expect to find metamorphic clast-rich layers in the sandstones, and these were not found.

(2) Metamorphic sediment may have been brought into the Marche region at an earlier time by fan complexes connected to the Southern Alps. Later turbidites and fan progradation could have redeposited this sediment along with great amounts of local limestone and other clastics. Samples that contain strained polycrystalline quartz also contain great amounts of sub-angular to subrounded carbonate grains that contrast with the sub- to well-rounded polycrystalline quartz grains.

Sediment mixing during transportation better explains the mixture of metamorphic and local sediment., because mixing would produce deposits containing both polycrystalline quartz and angular local limestone clasts, whereas Alpine sediment influx would produce Alpine-rich layers alternating with local carbonate layers. Ricci-Lucchi (1975) suggested that narrow, fault-bounded depressions (like the Coldigioco-Castellaro basin) were not connected to the northern basins, but independently received sediment from the surrounding areas of high relief. This would explain the small amount of alpine clasts found in the flysch in this basin. I consequently conclude that the Coldigioco- Castellaro basin received sediment from the growing anticlines and received very little from the Alps.

BASIN ANALYSIS

Although lack of outcrop and paleocurrent indicators make correlation and detailed mapping of the fan complex nearly impossible, thin section analysis and structural observations provide some clues to the depositional history of the basin. All of the outcrops studied are located near the older fault on the opposite side of the valley from the Cingoli anticline (see Fig. 2) Dips in this area dip toward the anticline indicating that this area was affected by the growth or existence of both the Cingoli anticline and the older thrust fault. Dips in the Turkey Pen section are lowest, suggesting that this section was deposited later in the evolution of the basin than the other two studied sections. Changes in dip within measured sections at Fornaci and Coldigioco North indicate growth of the anticline during deposition.

There is an abrupt change from hemipelagic deposition (the Bisciaro formation) to thick sequences of sandstone and conglomerate (Marnoso-Arenacea) in this area. In fact, the uppermost Bisciaro can be found within 150 m of the boulder conglomerate seen at Coldigioco North. The tectonic evolution of the basin seems to have begun abruptly with great influxes of clastic sediment. The present structure of the basin is complicated, making it difficult to reconstruct the fan complexes.

Figure 5 shows a generalized cross section of a small fault-bounded basin similar to the Coldigioco-Castellaro Basin. The size of the boulders in facies B at Coldigioco North indicate that the source area for these clasts was very close, perhaps within one kilometer. The likely source would be the older anticline, opposite of the Cingoli anticline. These conglomerates, along with the convoluted beds and graded conglomerates in Facies A, would correspond to the materials that slumped and slid down the passive slope in Figure 5A.

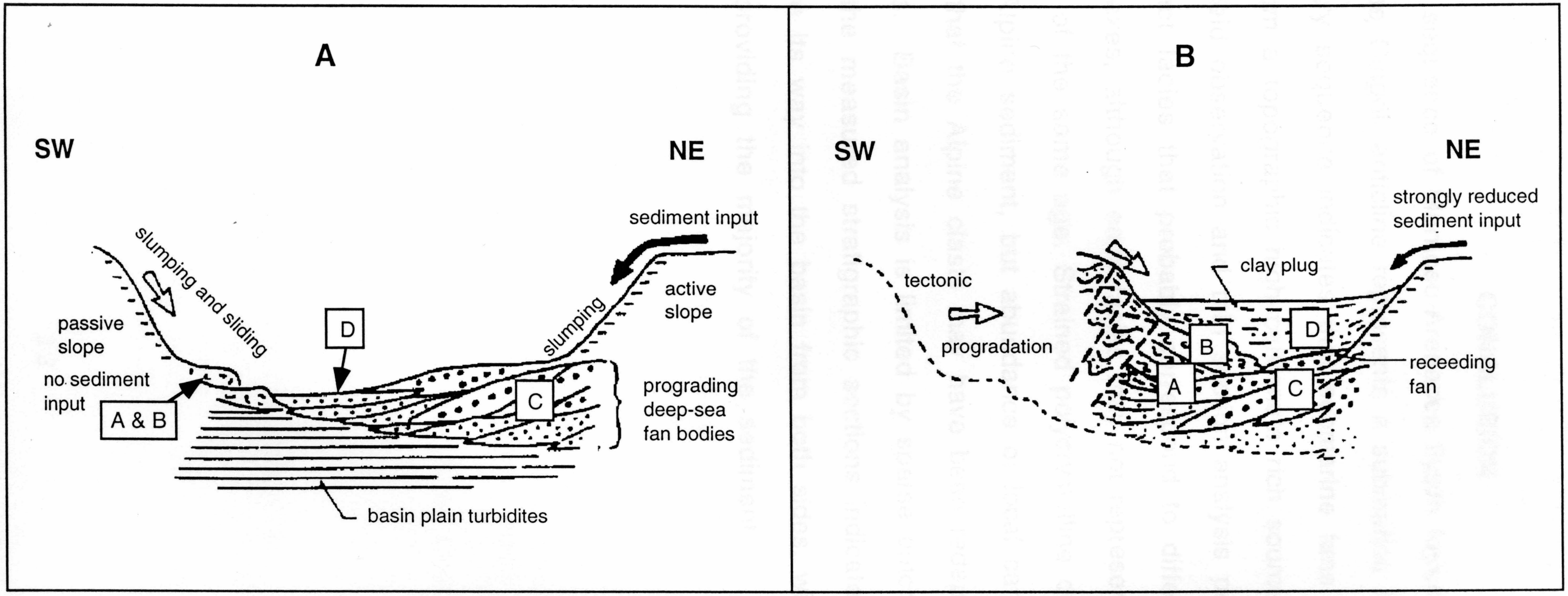
Facies C represents a section of prograding deep-sea fan bodies. Facies C grades from very poorly sorted, and with angular deposits at the base to moderately to well-sorted at the top. This facies was probably from sediment covering the Cingoli anticline that spread out across the basin.

The thick sequences of fining upward conglomerates and sandstones indicate periods of higher slope during which conglomerates were deposited that grade into the medium sandstones. The example of facies C found at Fornaci is probably older than the example found at the Turkey Pen section. Fornaci is dipping more steeply toward the center of the basin while the Turkey pen is nearly horizontal and was probably deposited in the later stages of the basin development.

The distal turbidites of Facies D was probably derived from the Cingoli anticline and not the older anticline. Facies D shows the greatest degree of rounding and smallest grain sizes of all the facies. These sediments could not have come from the closest anticline, but must have come from Cingoli.

Continued deformation of the basin has affected these sedimentary rocks as shown in Figure 5B.

Figure 5: **GENERALIZED TECTONIC AND SEDIMENTARY EVOLUTION OF COLDIGIOCO-CASTELLARO BASIN**



A. shows fan progradation into the basin from an active slope. B. shows basin after deformation in final stages of filling. Letters within figure show approximate locations of each facies on a single fan. (Modified from Ricchi-Lucchi, 1975)

CONCLUSION

The sequence of Marnoso-Arenacea flysch found in a small basin west of the Cingoli anticline represents a submarine fan complex. The sedimentary sequence indicates that submarine fans supplied sediments eroded from a topographic high carbonate rich source into the synclinal basin. Field observation and thin section analysis permit recognition of four distinct facies that probably correspond to different portions of the fan complexes, although each facies may not represent parts of the same fan or be of the same age. Strained polycrystalline quartz indicates some influx of Alpine sediment, but abundance of local carbonate clasts suggests that the Alpine clasts may have been redeposited with the local carbonates. Basin analysis is limited by sparse outcrops, but evidence found in the measured stratigraphic sections indicates that sediment may have made its way into the basin from both sides, with the Cingoli anticline providing the majority of the sediment.

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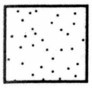
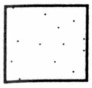
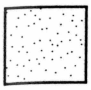
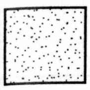
APPENDIX
Detailed Stratigraphic Columns of Measured Sections

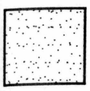
KEY TO LITHOLOGIC SYMBOLS

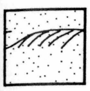
 coarse to very coarse sandstone

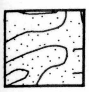
 medium sandstone

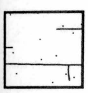
 fine to medium sandstone

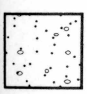
 very fine to fine sandstone

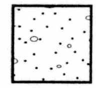
 laminated sandstone

 ripple cross laminated sandstone

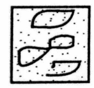
 convolutions

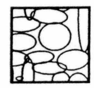
 calcareous sandstone

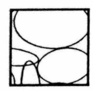
 granule conglomerate

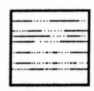
 pebble conglomerate

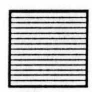
 coarser conglomerate beds

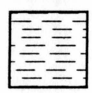
 concretions

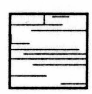
 cobble conglomerate

 boulder conglomerate

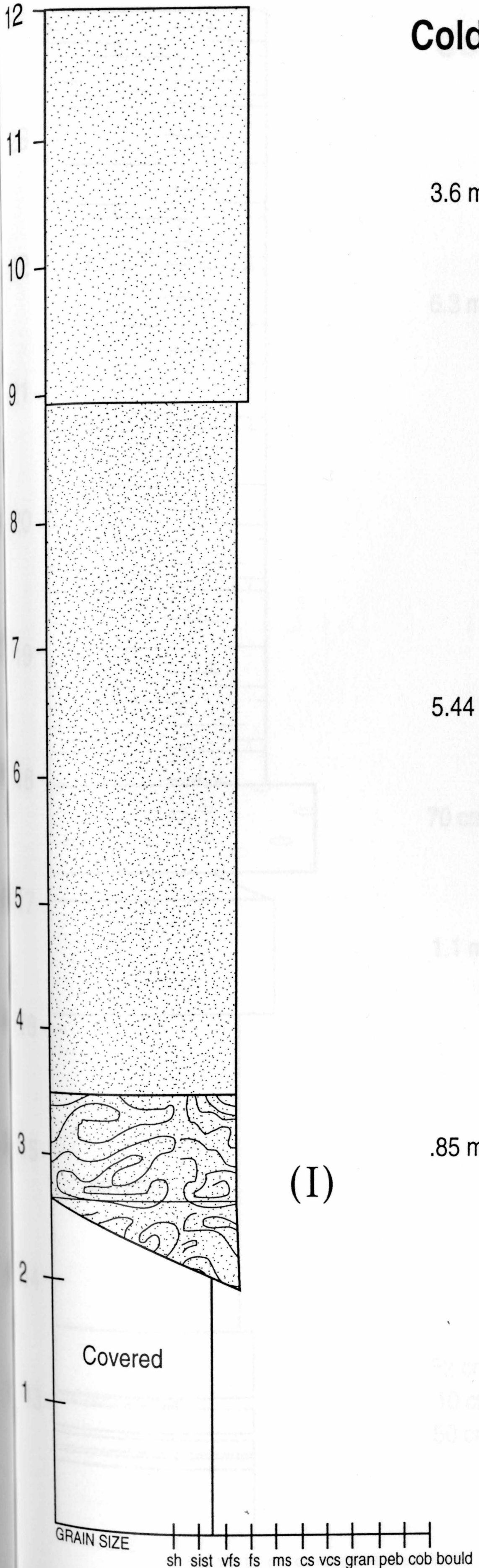
 siltstone

 laminated mudstone

 mudstone

 marl

Coldigioco North Section

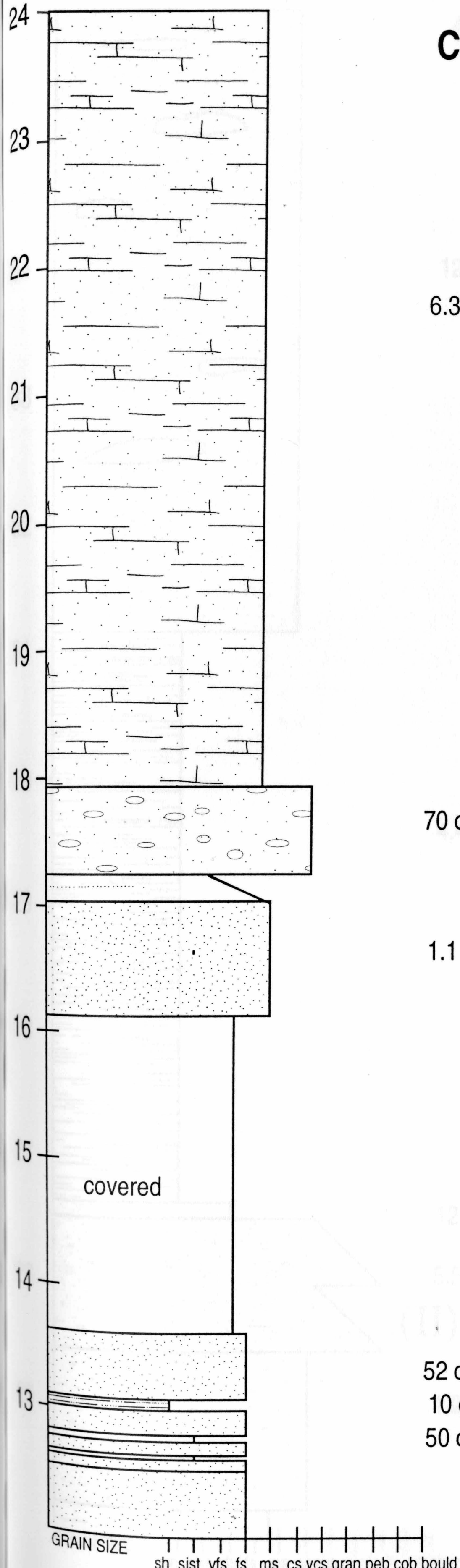


3.6 m tan fs

5.44 m tan vfs/fs with parallel lamination and distorted flute casts

.85 m thick distorted tan vfs/fs with high mica content

Coldigioco North Section



6.3 m badly weathered poorly exposed fs/ms with convoluted white porous calcitic layers 3-8 cm thick

70 cm very badly weathered and poorly exposed cs/vcs conglomerate with ls pebbles and sist intraclasts

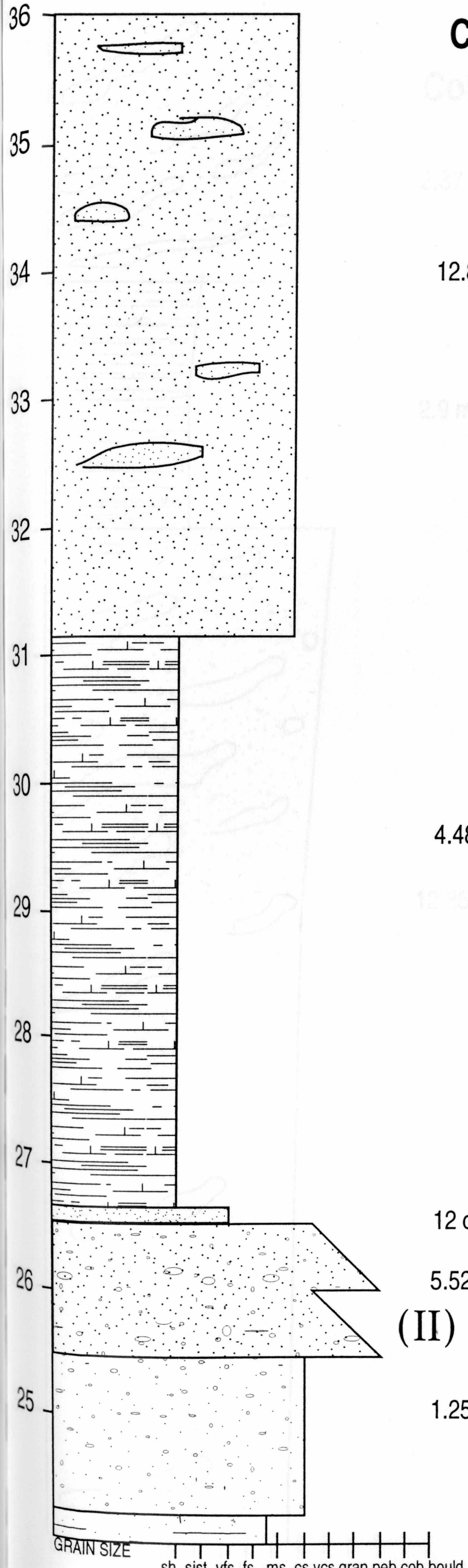
1.1 m structureless tan ms. top 20 cm grade into vfs/sist

52 cm tan fs

10 cm thick white porous calcitic bed

50 cm tan fs interbedded with 2-4 mm thick parallel laminated brown silty layers

Coldigioco North Section



12.85 m tan ms/cs with local concretions

4.48 m pale grey to brown marl

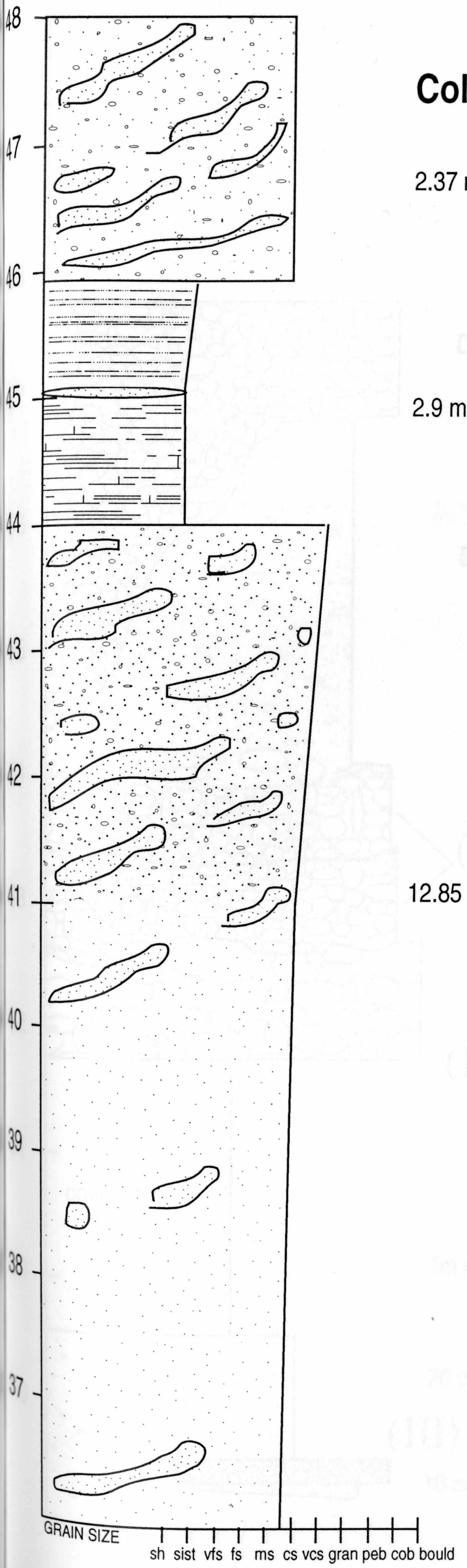
12 cm tan vfs with some ripples

(II)

5.52 m- two sets of beds fining upward. Bottom of beds is gran/pebb conglomerate fining upward into cs with granules, similar in composition to below.

1.25 m tan cs with granules of wht ls, blk, brn, and grn chert, quartz, biotite, and muscovite. Pebble lags in horiz lam. small concretions 1-2 cm thick

Coldigioco North Section

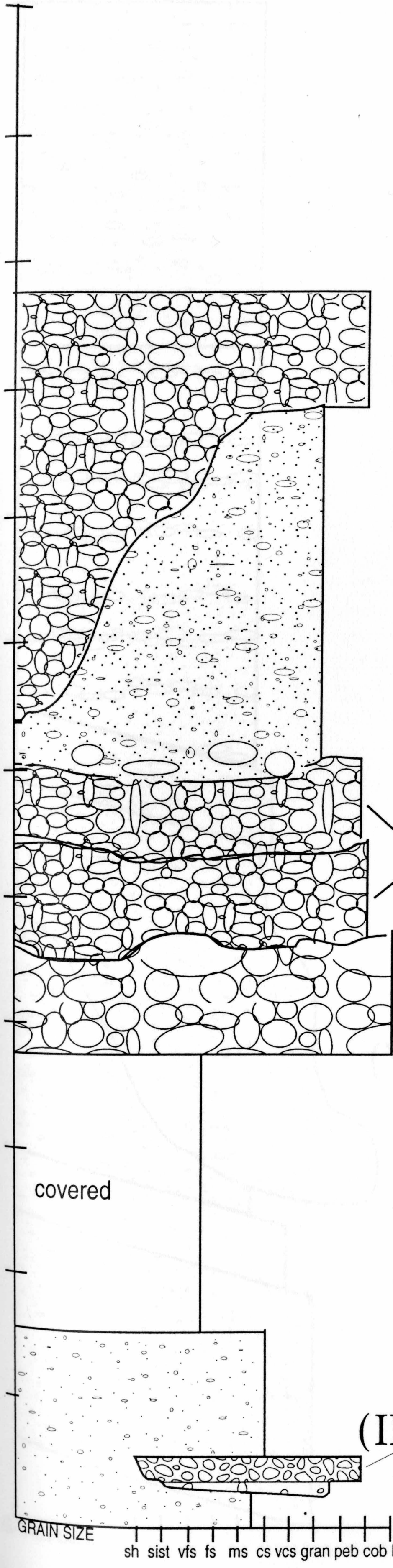


2.37 m tan ms/ cs with aprox. 5% granules and a few pebbles grains all of white ls. small% mica. blk, and grn chert in ss. large- up to 1 m long 20cm thick concretions. defining channels?

2.9 m dark brown to grey marl grading into brown to light brown sist with floating fs/ms grains
concretion 70 cm below base

12.85 m tan ms/cs cont.
top 3 m grade into cs/vcs with local ls pebble beds in cs (5mm) becoming more abundant near top.
concretions abundant in top 5 m.

Coldigioco North Section



Debris flow #5- 90 cm thick in thinnest spot. Poorly exposed and badly weathered. Best exposure seen just above DF #4 where channel outline can clearly be seen. ls cobbles in matrix of vcs

Debris flow #4 - 32cm- 2.7 m thick cs/ vcs with abundant pebbles of wht ls, and blk, red, and grn chert. Some pebbles in stingers, some randomly scattered. large ls cobbles in bottom of bed.

Debris flow #3- 60-75 cm thick conglomerate of subangular to rounded ls cobbles few mdst and ss cobbles. Matrix is cs

(V)

Debris flow #2- conglomerate of subangular to rounded clasts of wht to lt gry ls in matrix of cs. Clasts slightly smaller on sides of large boulder in Bed 1 but become larger and unsorted within 12 cm of boulder.

Debris flow #1- 1.15 m measurable section. Bed probably continues into covered area. Boulder conglomerate with subangular to well rounded clasts up to 1m x 1.3 m. Clasts mostly white ls, but shale, mudstone, coarse ss, & fine sandstone also present. Matrix is cs and mud.

(IV)

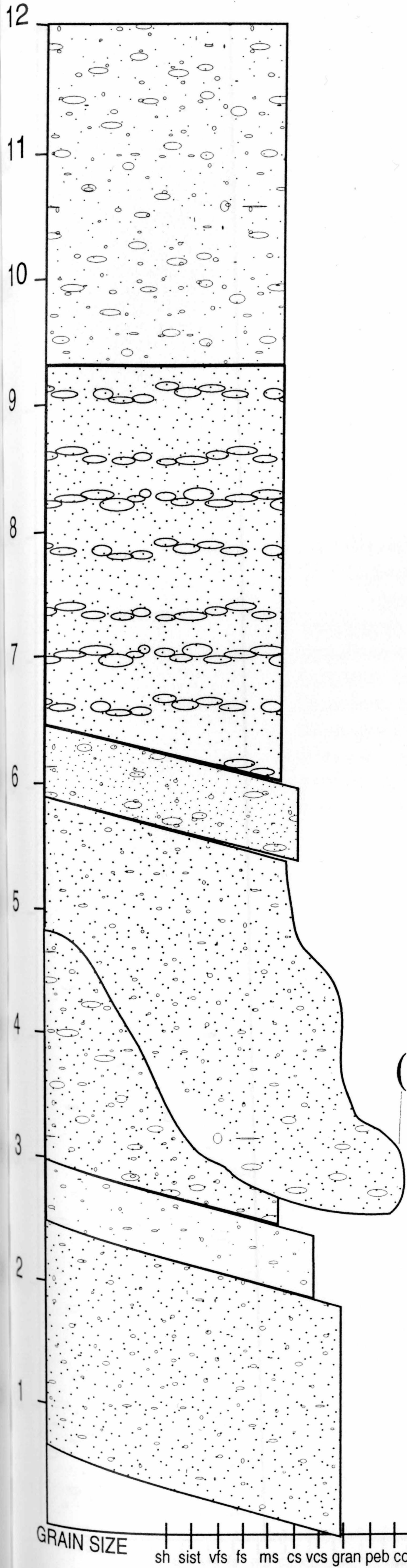
1m cs with similar comp to below. Wht ls granules and pebbles dispersed. few brn mdst intraclasts similar to below in lower part of bed. Concretion of wht ls pebb & mdst intraclasts in top 15 cm

20 cm vcs cobble conglomerate. terminus of channel poorly defined few clasts near channel edge. Conglomerate of intraclasts of brn mudst & lesser wht ls. ss clast 35 x 4 cm

(III)

10 cm cs wtih abundant pebb of wht ls rare ss intraclasts up to 8 by 4 cm. ls clast up to 3.5 cm ranging from rounded to flattened pebb

Fornaci Section



fining upward sequence with large scale low angle laminae

3.3-2.8 m poorly sorted mix from fs-gran
alternating gran rich and gran poor layers in horizontal laminae
angle intersection of laminae on broad scale from m 7 to m 9.2

.6 m very poorly sorted from vfs to pebbles of wht ls

.5 m at top of channel poorly sorted ms with about 10% coarser up to granules

(VII)

.8 m at base of channel, pebbly conglomerate wtih many wht ls clasts grades up into poorly sorted mix of about 40% fs, 20% gran/vcs, 40%cs/ms. grades into ms

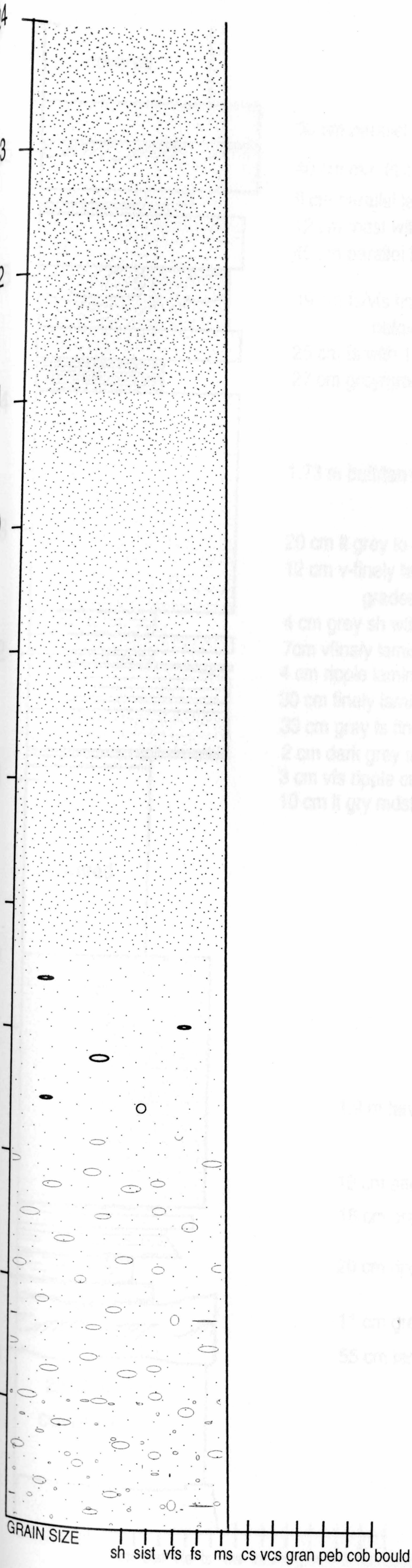
20-170 cm cs with 5-10% vcs/gran up to 1 1/2 across of wht ls clasts

60 cm poorly sorted mix of ms to granules same comp as below poorly defined cm thick coarse granular layers

(VI)

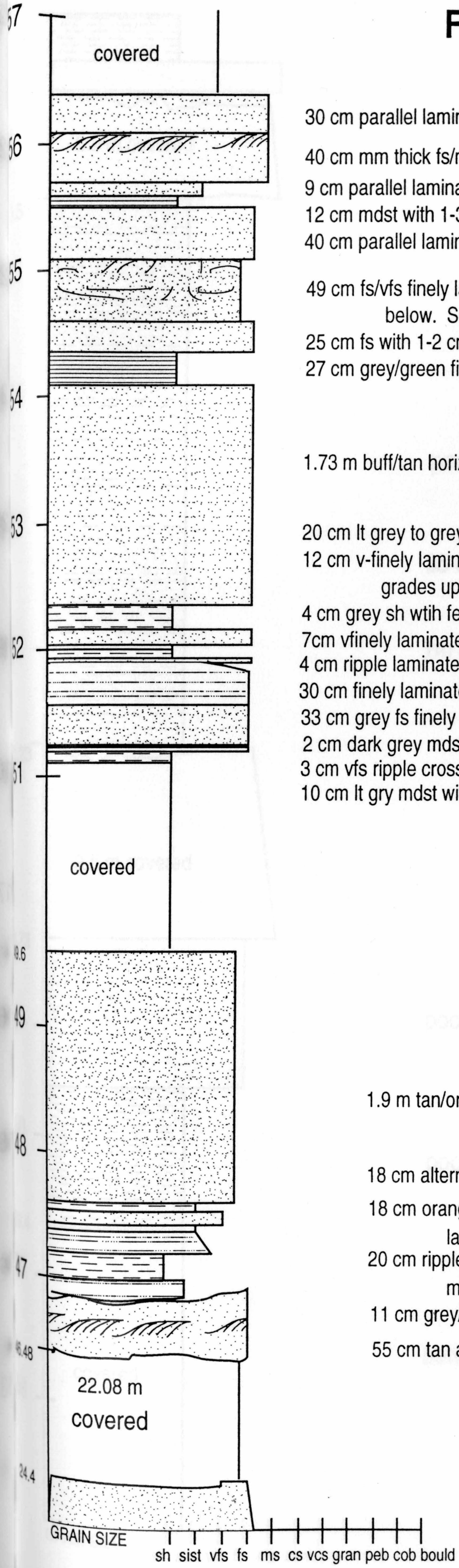
1.8 m granular conglomerate with pebble intraclasts of grey mdst up to 3 cm in diameter, also pebbles of wht ls, grn, red, & blk chert

Fornaci Section



15.2 m fining upward sequence cont. fining from ms/ cs to fs at top
buff colored fs near top with abundant mica.

Fornaci Section



30 cm parallel laminated ms/fs

40 cm mm thick fs/ms ripple cross laminae

9 cm parallel laminated fs

12 cm mdst with 1-3 mm thick silt to fs laminae grading from lt to dark grey

40 cm parallel laminated fs

49 cm fs/vfs finely laminated with convoluted ripple cross laminae same color as below. Some mm thick clay laminae

25 cm fs with 1-2 cm thick lt & dark tan laminae

27 cm grey/green finely laminated mdst with .5-3 cm beds fs beds

1.73 m buff/tan horizontally laminated fs

20 cm lt grey to grey mdst with widely spaced 1-3mm vfs laminae

12 cm v-finely laminated, cross laminated, and convoluted fs. mm thick mdst laminae grades up into 5cm vfs laminated mdst

4 cm grey sh wtih few mm thick sist laminae

7cm vfinely laminated fs & grey mdst

4 cm ripple laminated fs

30 cm finely laminated fs/mdst grading up into vfs/sist laminated mdst

33 cm grey fs finely laminated on mm scale with orange vfs

2 cm dark grey mdst

3 cm vfs ripple cross laminated fs

10 cm lt gry mdst with thing vfs laminae less than 3mm

1.9 m tan/orange horizontally laminated vfs/fs

18 cm alternating orange vfs & grey sist

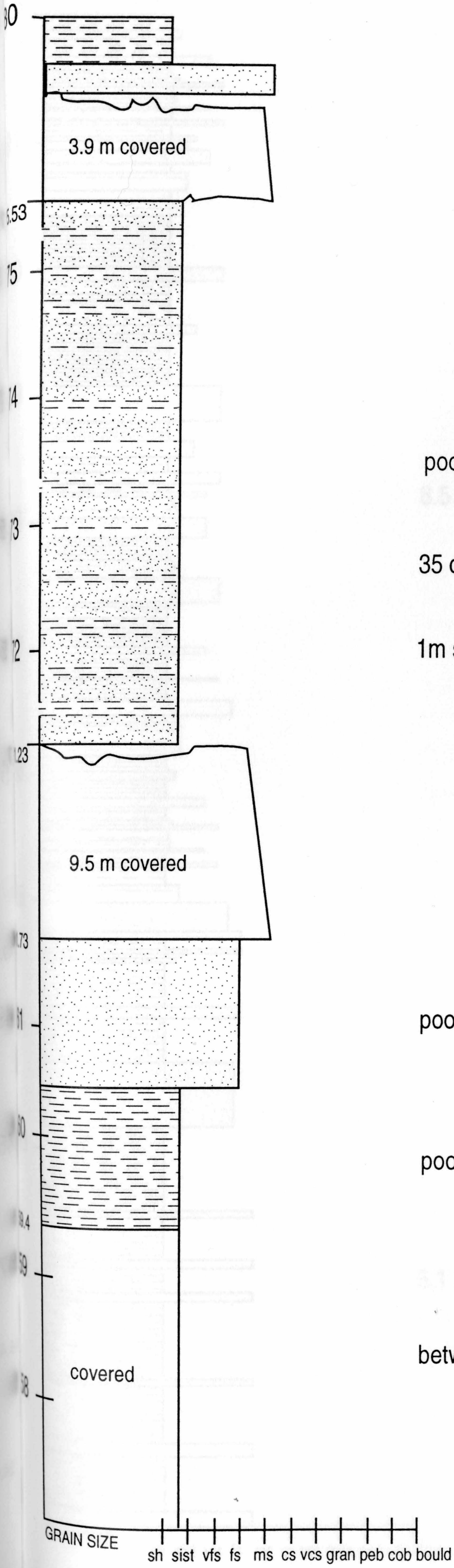
18 cm orange ripple laminated vfs & lt tan sist grading into gry parallel laminated sist

20 cm rippled orange and grey sist grading into parallel laminated grey mudstone

11 cm grey/green sist/mdst laminated with orange fs (2-5mm)

55 cm tan and dark brn fs with some climbing ripples -irregular contact

Fornaci Section



poorly exposed interbedded vfs 50% and mdst 50% on decimeter scale

35 cm buff/grey fs with ripple cross lamination

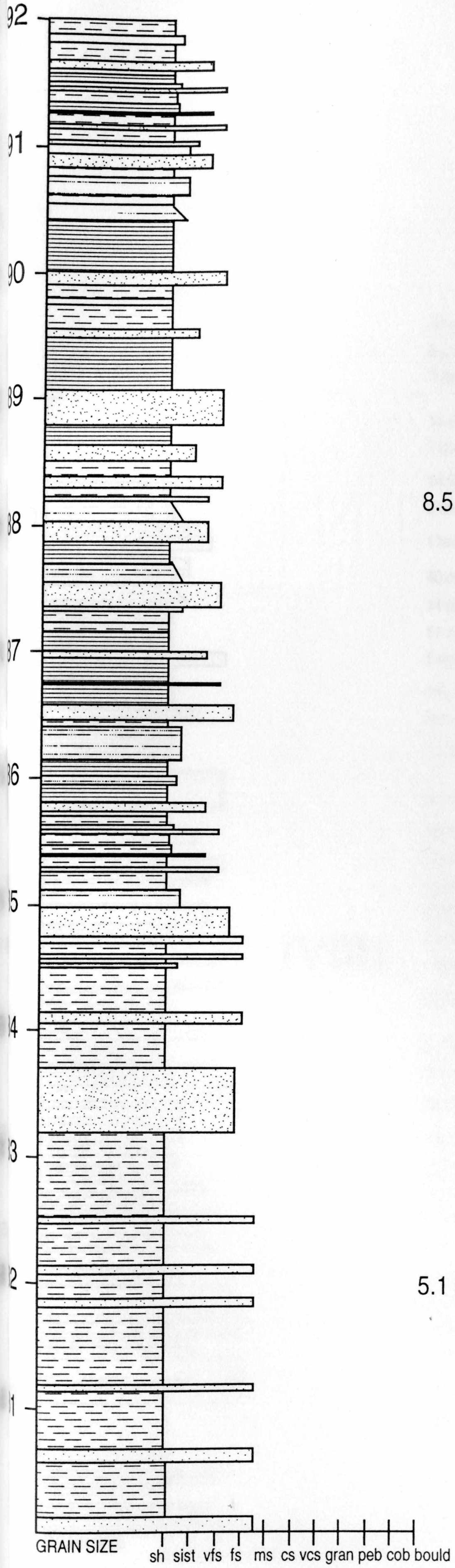
1m sist/vfs laminated mdst interbedded with lt orange vfs (beds 4-7 mm thick) making up 10-15% of beds
2 massive mdst beds. first 5 cm at .3m above bottom. Second 10 cm at .55 cm above bottom

poorly exposed lt tan fs. badly weathered. Some horiz. laminae

poorly exposed mdst and fs

between m 56.45 and m 59.4: poorly exposed thick fs, vfs beds and minor mdst beds

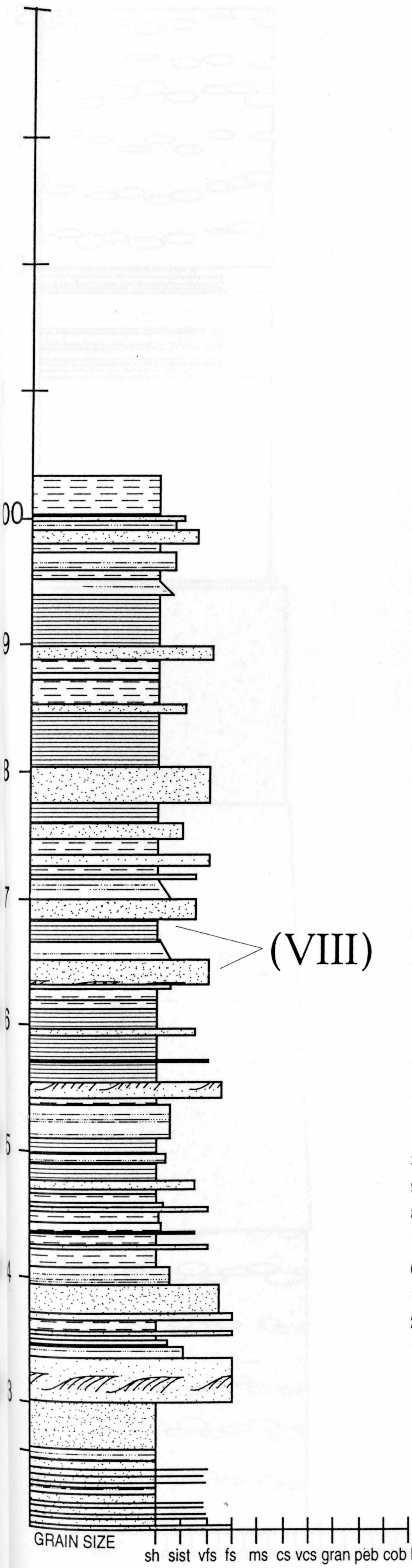
Fornaci Section



8.5 m poorly exposed to well exposed but inaccessible outcrop of mdst and thin sands similar to above section

5.1 m poorly exposed section
ms/fs forms base and similar beds 10-15 cm thick are widely spaced in massive laminated mdst tens of cm thick.
80 cm from top is a fs bed 50 cm thick

Fornaci Section

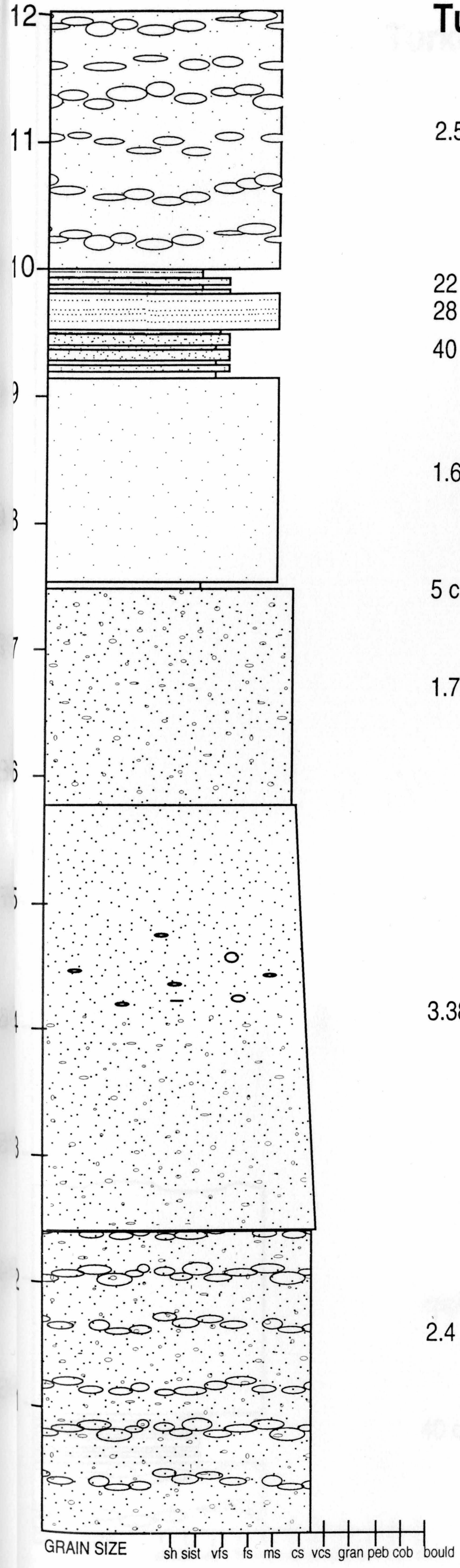


32 cm brn/gry mdst
5 cm interbedded vfs/mdst
7 cm muddy sist

11 cm sist/vfs
7 cm lt gry finely laminated mdst
14 cm muddy sist
6 cm lt gry mdst
11cm muddy sist grading into massive mdst
40 cm gry/tan massive mdst with 2-3 lt gry laminated mdst beds 2-4 cm thick
11 cm ripple cross laminated vfs
11 cm tan massive mdst
5 cm lt gry finely laminated mdst
20 cm tan/lt gry massive mdst
8 cm sist rippled at bottom
42 cm dk gry/brn generally massive mdst
29 cm vfs with draped ripples, parallel lamination in lower section
16 cm massive mdst-gry
12 cm ripple cross laminated mdst
12 cm massive mdst
8 cm ripple bedded and ripple cross laminated vfs
8 cm massive mdst
4 cm vfs/sist
16 cm laminated silty mdst grading to massive mdst
16 cm silt/vfs
17 cm laminated mdst with widely spaced 1-3 mm thick vfs beds
16 cm silty mdst grading into massive mdst
19 cm vfs
3 cm silty mdst
9 cm massive mdst
8 cm laminated mdst with widely spaced <1 cm vfs beds
17 cm laminated mdst grading to massive mdst
6 cm 1-2 cm vfs beds & laminated silty mdst
18 cm massive mdst wtih a few laminated mdst intervals
2 cm vfs
17 cm mdst laminated at top and bottom

35 cm buff/grey fs with ripple cross lamination

1m sist/vfs laminated mdst interbedded with lt orange vfs (beds 4-7 mm thick) making up 10-15% of beds 2 massive mdst beds. first 5 cm at .3m above bottom. Second 10 cm at .55 cm above bottom



Turkey Pen Section

2.55 m ms with 20 cm thick beds of elongate ls pebbles from 7-27 cm long in four or five parallel laminated stringers. Bottom of first bed 8cm above base. Second bed 4 cm above top of first.

22 cm interbedded vfs & sist

28 cm parallel laminated fs/ms. no granules or pebbles

40 cm interbedded rippled orange vfs and tan vfs/sist with pebbles of wht ls. vfs beds 3-10 cm thick, vfs/sist 3-5 cm thick

1.6 m ms wtih 1-2% granules, < .5% pebbles

5 cm green/grey mdst and orange siltstone with ripples in siltstone. pinches out across outcrop and reappears as thinner 2-3 cm lense of wht ls pebbles

1.72 m tan ms/cs with abundant granules similar to below and 1-2% ls pebbles

3.38 m tan ss cs/vcs fining upward into ms/cs with fewer granules than below and very few pebbles (<1%). ss similar in comp to below. Concretions smaller.

2.4 m tan cs/vcs with abundant granules of wht ls blk, grn, & red chert. pebbles of wht ls in roughly parallel lamination intraclasts of grey marly ls 5-18 cm large concretions present

Turkey Pen Section

ms? too high to see close up

40 cm interbedded mdst and vfs. beds 3-10 cm