Riv. It. Paleont. Strat.	v. 90	n. 4	pp. 565–603	Marzo 1985

QUATERNARY STRATIGRAPHY AND SOIL DEVELOPMENT AT THE SOUTHERN BORDER OF THE CENTRAL ALPS (ITALY): THE BAGAGGERA SEQUENCE

MAURO CREMASCHI*, GIUSEPPE OROMBELLI** & JOHN C. SALLOWAY***

Key–words: Stratigraphy, Pleistocene, Palaeomagnetism, Paleopedology, Soil forming processes, Palaeolithic artefacts, Lombardy.

Riassunto. La stratigrafia del Quaternario ed i processi pedogenetici al margine meridionale delle Alpi centrali (Italia): la successione di Bagaggera.

La successione stratigrafica, venuta in luce nelle cave per argilla di Bagaggera viene studiata in dettaglio. In base alla stratigrafia paleomagnetica e alle evidenze archeologiche in essa contenute, è accertato che la successione copre un intervallo cronologico che dal Pleistocene inferiore si estende fino all'ultimo periodo glaciale (ultimo apice glaciale della glaciazione würmiana).

L'evoluzione sedimentaria del bacino, ricostruita mediante i caratteri sedimentologici e petrografici del riempimento, risulta determinata ad un tempo dall'evoluzione tettonica e dalle variazioni climatiche pleistoceniche, sulle quali si è particolarmente accentrata l'attenzione degli Autori. Per l'intero Pleistocene sono documentate cinque distinte fasi glaciali, delle quali soltanto le due più recenti sono testimoniate da depositi direttamente connessi a fronti glaciali nella prossimità del sito.

Intercalati ai sedimenti e ad essi sovrapposti sono stati osservati, descritti ed analizzati, cinque differenti paleosuoli. Essi documentano che, per gran parte del Pleistocene, operarono nell'area processi pedogenetici non molto diversi da quelli postglaciali: decarbonatazione, lieve rubefazione e forte traslocazione delle argille.

Il paleosuolo più antico, evolutosi a partire dalla roccia flyschioide del substrato, mostra al contrario caratteri pedogenetici assai più spinti e probabilmente di differente ambiente pedoclimatico. E' inoltre discusso il significato genetico e stratigrafico di alcune figure pedologiche che ricorrono frequentemente nei paleosuoli del pedemonte lombardo.

Abstract. A complex sequence exposed in a clay pit, near Bagaggera, is described in some details. Palaeomagnetic stratigraphy and archaeologic finds indicate that the sediments of the Bagaggera basin accumulated at least from Early Pleistocene up to Late Pleistocene. The sedimentary development,

---

*Centro di Studio per la Stratigrafia e Petrografia delle Alpi Centrali, C.N.R., Via Mangiagalli 34, Milano.

**Dipartimento di Scienze della Terra, Università degli Studi di Milano, Via Mangiagalli 34, Milano.

***Department of Geophysics, University of Edinburgh, Mayfield road, Edinburgh EH9 3JZ.

– The present work was carried out with the contributions of the Consiglio Nazionale delle Ricerche and of the Ministero della Pubblica Istruzione (Programma di ricerca "Geologia delle pianure italiane"). M. Cremaschi for the pedologic and petrographic part, G. Orombelli for the stratigraphic part, J. Salloway for the palaeomagnetic part.

reconstructed on the ground of sedimentary, petrographic and mineralogical evidences, has been determined by climatic variations and tectonic activity. Five glacial stages are recorded in the sedimentary sequence, the oldest one dating back to Early Pleistocene, and only the last two are directly connected with the front of the Alpine glaciers.

Five different paleosols are interlayered in the basin fill; they indicate that, during Interglacial periods of Middle and part of Early Pleistocene, soil forming processes were not very different from those which operated in Postglacial times. On the contrary the oldest paleosol, dating back to Early Pleistocene or Late Pliocene, is due to stronger weathering and probably developed in a different pedoclimatic environment. Further the stratigraphic and genetic meaning of some soil features, very frequent in Lombard paleosols, is discussed.

1. Introduction. (M. C., G. O.).

A sequence of Quaternary deposits is exposed at Bagaggera, a small locality near Montevecchia (Como), in an area which has been almost entirely surrounded but never covered by the Alpine glaciers. Just because never reached by glaciers the Bagaggera sequence is particularly rich in stratigraphic evidences of various types and, on the other hand, being so near to glacial and fluvioglacial deposits, it can be reasonably compared with them.

For this reason the stratigraphic sequence of Bagaggera is of great importance for the interpretation of the Quaternary stratigraphy of the southern margin of the Alps.

1. 1. Geologic setting.

The Bagaggera sequence has been deposited inside the Curone valley, a small valley draining the SW slope of the Montevecchia hill (479 m), consisting of Cretaceous–Paleocene sandstone and marly limestone (Bergamo Flysch and Scaglia formations).

During Quaternary the Curone valley has been dammed by fluvial deposits and the Montevecchia hill several times has been reached and almost entirely surrounded by the Brianza and Lecco piedmont lobes of the Adda Glacier (Fig. 1). The alluvial dam is represented by a terrace 25 m high with respect to the adjacent Würm outwash plain. Although the stratigraphy of this terrace is not entirely exposed, the bulk of it is composed of conglomerate belonging to the Ceppo of Adda formation, ascribed to the Upper Pliocene (?) – Lower Pleistocene (Orombelli, 1979).

The alluvial damming of the Curone valley generated a small lake where lacustrine, fluvial and eolian sediments were deposited.

1. 2. Previous studies.

The stratigraphic sequence of Bagaggera was firstly described by Venzo (1948, 1952, 1955). According to this author in the clay pit of Bagaggera the following sequence was exposed, from top to bottom:

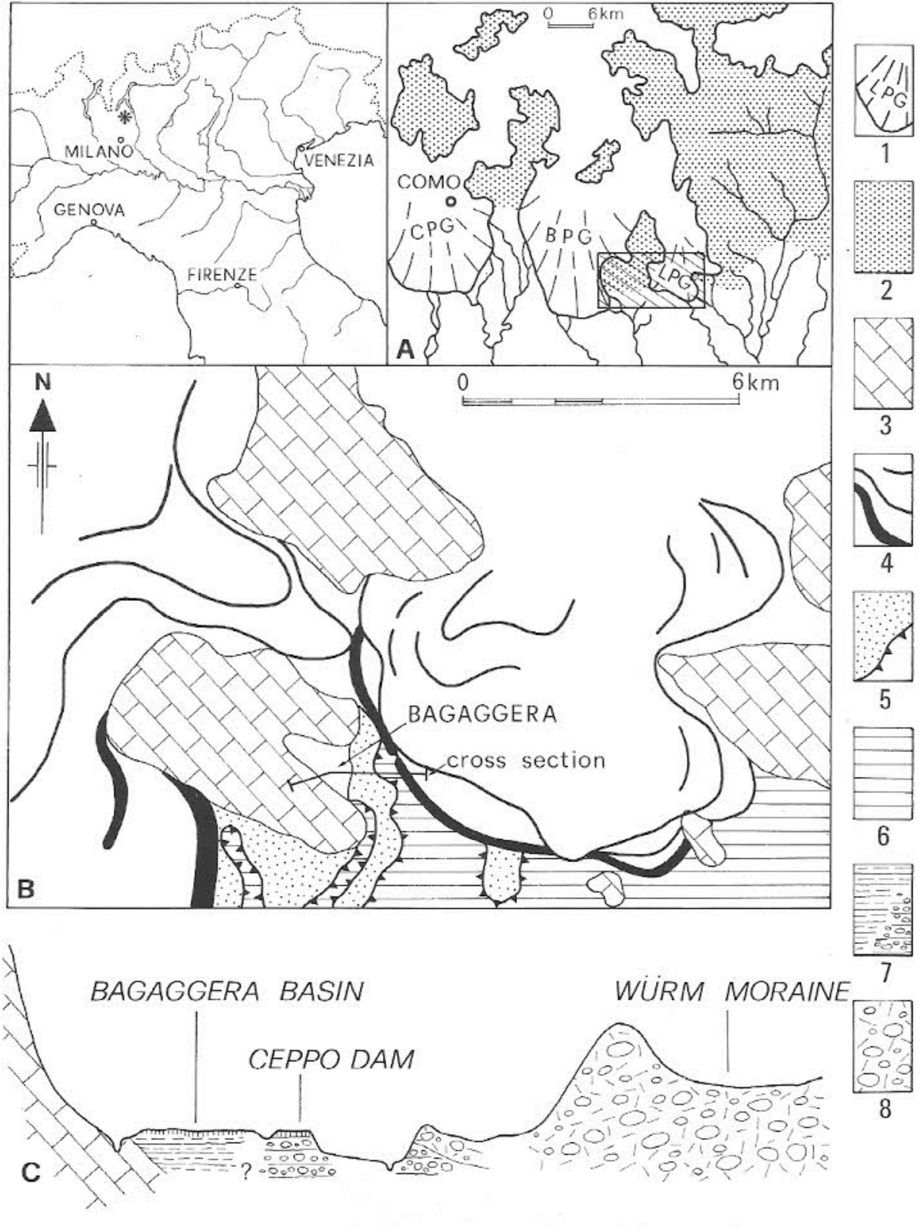

Fig. 1 – Index and geologic sketch maps of Bagaggera and surrounding area. A) The Adda glacier during the Würm maximum. 1) Adda glacier: CPG) Como lobe; BPG) Brianza lobe; LPG) Lecco lobe; 2) non glaciated mountain area.
B) Geologic map. 3) Bedrock; 4) Moraine ridges; 5) Oldest terraces; 6) Würm outwash plain.
C) Geologic cross section. 7) Bagaggera fill and Ceppo dam; 8) till.

a) reddish brown clay (5 m);
b) grey laminated clay with fishes and *Unio* (9 m);
c) light grey clayey sand, with remains of *Cervus*, *Abies alba* and pollens of *Abies*, *Pinus* and *Fagus* (2 m);
d) blue–grey laminated clay (3 m).

Venzo thought that the lacustrine basin had been dammed by the Lecco piedmont glacier and related the entire sequence to the Mindel glaciation. The same opinion was maintained by Gabert (1962), while Chardon (1975) ascribed to a Mindel moraine the damming of the lake but referred to the Riss the lacustrine fill.

Recently Bucha & Sibrava (1977) and Billard et al. (1982) reported preliminary stratigraphic and palaeomagnetic results: in particular a clear reversal in magnetic inclination from negative to positive was observed in the lower part of the lacustrine sequence, which was correlated with the Matuyama/Brunhes boundary.

2. Stratigraphy. (M. C., G. O).

At the present time a large clay pit and other minor excavations extensively expose the sediments of the Bagaggera basin. While the central part of the lacustrine basin has been almost entirely exploited, the sediments at the margin of the basin are still preserved.

Along the studied exposures, from North to South, two sub–basins separated by a bedrock threshold can be recognized. Fig. 2 shows a reconstructed cross–profile of the basin fill. Nine sections have been studied in detail (Fig. 3). Ten stratigraphic units or sub–units have been identified on the basis of lithostratigraphic criteria. At least five superposed paleosols are present as well as four major unconformities. Correlations between different sections have been traced on the basis of direct lateral continuity of the lithostratigraphic units or by means of the palaeomagnetic results. Artefacts are present inside two superposed layers in the topmost part of the sequence.

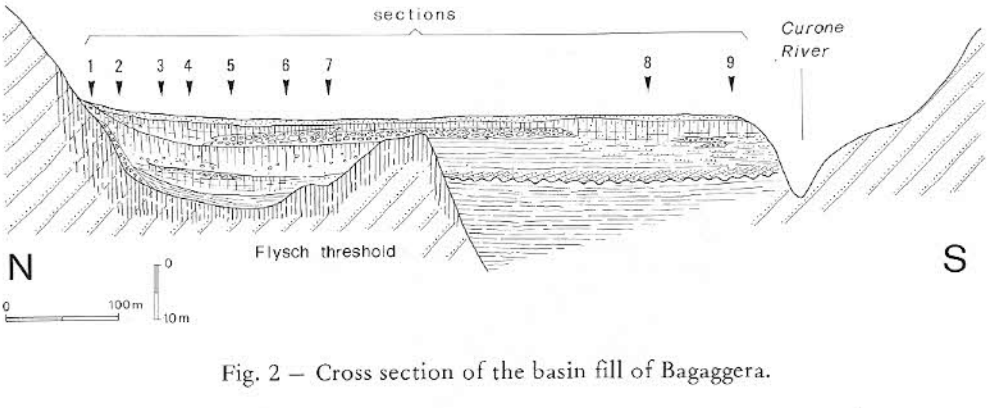

Fig. 2 – Cross section of the basin fill of Bagaggera.

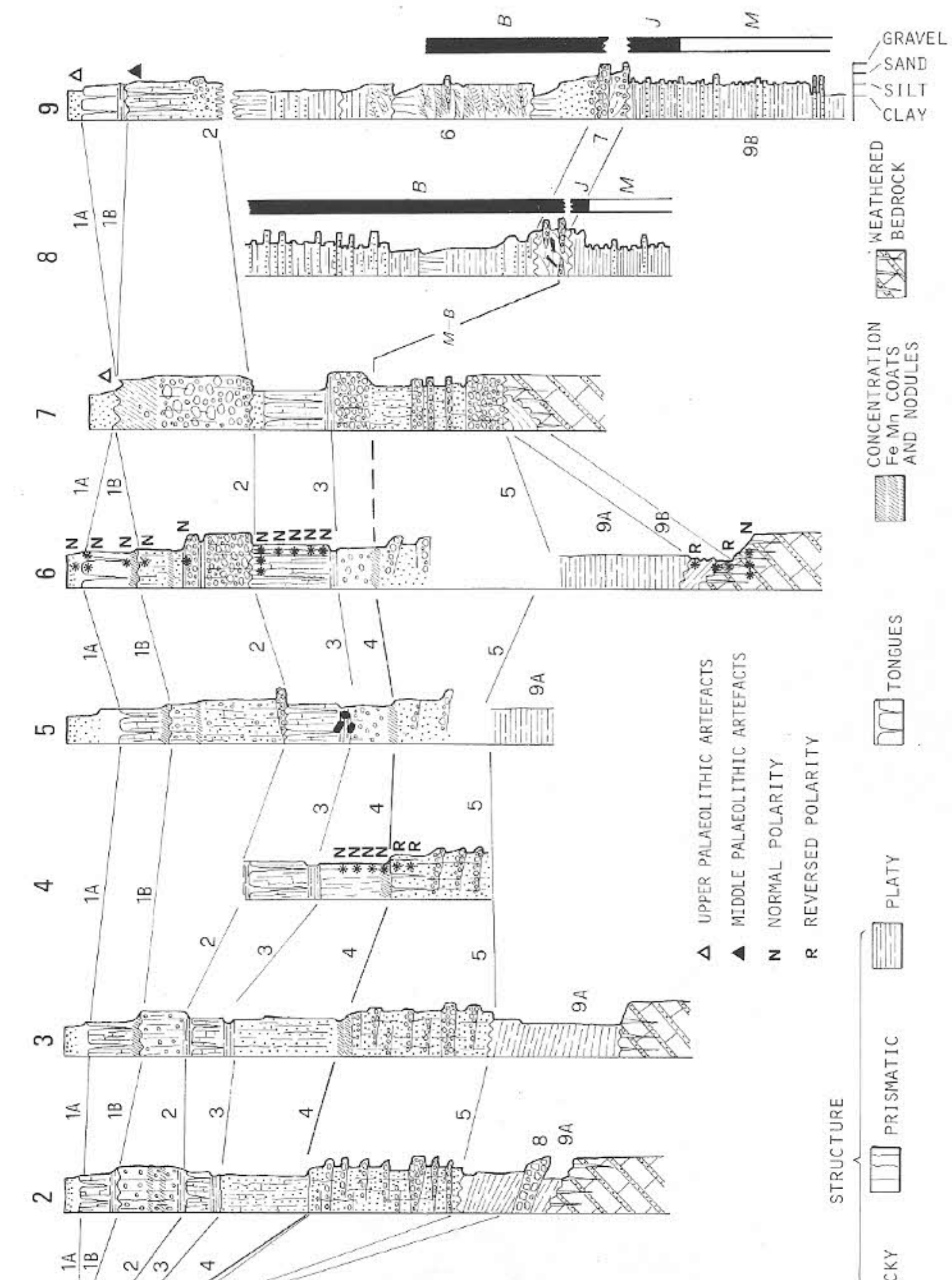

Fig. 3 — Stratigraphic sections measured in the Bagaggera sequence.

2. 1. Lithostratigraphy.

The following units have been recognized, from top to bottom (Fig. 4).

1) *Loess.* A cover of eolian silt is present at the top of the Bagaggera sequence and two different loess sheets can be identified:

1A) Sandy$_{18}$ clayey$_{21}$ silt$_{61}$ (1) massive, friable, yellowish brown 10YR 4/3, with a maximum thickness of 50 cm, thinning towards the edges of the basin. It fills up small gullies that cut the underlying loess sheet and buries an Upper Palaeolithic settlement with artefacts and charcoal of *Pinus* and *Betula* (2).

1B) Sandy$_{12}$ clayey$_{28}$ silt$_{60}$, massive, firm, yellowish brown 10YR 4/6, rich in ferri–manganesiferous nodules and concretions, with a maximum thickness of about 1 m, thinning toward the edges of the basin. This loess sheet is laterally discontinuous and its lower boundary is marked by an erosional surface.

The two loess sheets are included in soil unit S1.

2) *Fluvial sand and gravel.* This unit consists of alternating sand and gravel layers in various proportions. At the southern border of the basin (Fig. 3, section 9) layers of coarse sand with lenses of fine gravel about 1 m thick, alternate with layers of sandy$_{18}$ silty$_{38}$ clay$_{44}$ and with sandy$_{26}$ clayey$_{26}$ silt$_{48}$, massive, 20–30 cm thick. The color of the matrix ranges from 7.5YR 4/6 strong brown to 10YR 5/6 yellowish brown. At the top a layer of sandy$_{17}$ clayey$_{26}$ silt$_{57}$, contains in its upper part Middle Palaeolithic artefacts.

In the central part of the basin this unit (sections 6, 7) consists of gravel with subrounded to rounded pebbles, up to 12 cm of intermediate diameter, in beds separated by sand intercalations with low angle oblique laminations. Color of the matrix 7.5YR 4/4, dark brown.

In the northern part of the basin (sections 2, 3, 5) gravelly sand is present, thinning and passing to clayey$_{30}$ sandy$_{34}$ silt$_{36}$ near the margin of the basin (section 1). Color of the matrix 7.5YR 4/4, dark brown. On this unit the paleosol S2 is developed.

3) *Strong prismatic loam.* This unit is present only in the northern sub–basin and consists of sandy$_{10}$ clayey$_{40}$ silt$_{50}$ with scattered siliceous granules and small pebbles. No sedimentary structure is evident while a strong, coarse prismatic soil structure is present. Overall color 5YR 4/6 yellowish red. Large subangular clasts of laminated clayey silt (deriving possibly from unit 9A) are locally present at the base. At the top this unit consists of sandy$_{13}$ clayey$_{30}$ silt$_{57}$, without stones, of possible eolian origin. Paleosol S3 overlies this unit.

4) *Gravelly loam.* This unit is present only in the northern sub–basin and is represented by sandy$_{14}$ clayey$_{30}$ silt$_{56}$ with scattered small pebbles, without any obvious sedimentary structure. Overall color 7.5YR 5/6 strong brown.

Pebbles increase in size and frequency towards the threshold which closes the sub–basin (sections 5, 6) to the South. This unit too is overlain by paleosol S3.

5) *Fluvial sand and gravel.* This unit is present only in the northern sub–basin. It consists of sandy clayey silty beds and of gravelly beds with silty sandy clayey matrix. Overall color 7.5YR 5/4. Pebbles, up to 6 cm of intermediate diameter, are subrounded to rounded.

Gravel layers increase in thickness and frequency towards the southern margin.

6) *Fluviolacustrine sand and silt.* This unit is present only in the southern sub–basin and is 9 meters thick. Two different facies have been observed. In section 8 this unit (6/1) is

---

(1) Small numbers indicate the percentage of sand, silt and clay in samples.

(2) Determined by L. Castelletti.

represented by massive clay layers with fresh water molluscs and plant remains and oogons of *Characeae*, passing upwards to thin–laminated clayey silt with intercalations of thin beds of fine and medium sand, locally cemented. In the upper part of the unit are present coarse sand and fine gravel beds, about 10 cm thick. Color ranges from 2.5Y 6/2 light yellowish grey to 10YR 5/6 yellowish brown. In the section 9 this unit (6/2) is composed of at least four fining–up sequences of different thickness. Each sequence has an erosional base and begins with medium and coarse cross–stratified sand with small channels, filled with fine gravel, followed upward by medium and fine sand with ripple and low angle oblique laminations. Overall color ranges from 7.5YR 5/8 to 5Y 6/3, light yellowish brown.

At its top each sequence ends with silty clay and clay layers, massive, dark coloured and with an organic content higher than in the underlying sediments.

7) *Siliceous sand and gravel.* This unit is present only in the southern sub–basin. It is composed of cross–bedded medium and coarse sand and of lenses of fine gravel. Overall color 5Y 6/3. Clasts are entirely made of angular chert and of broken quartz pebbles. Maxi-

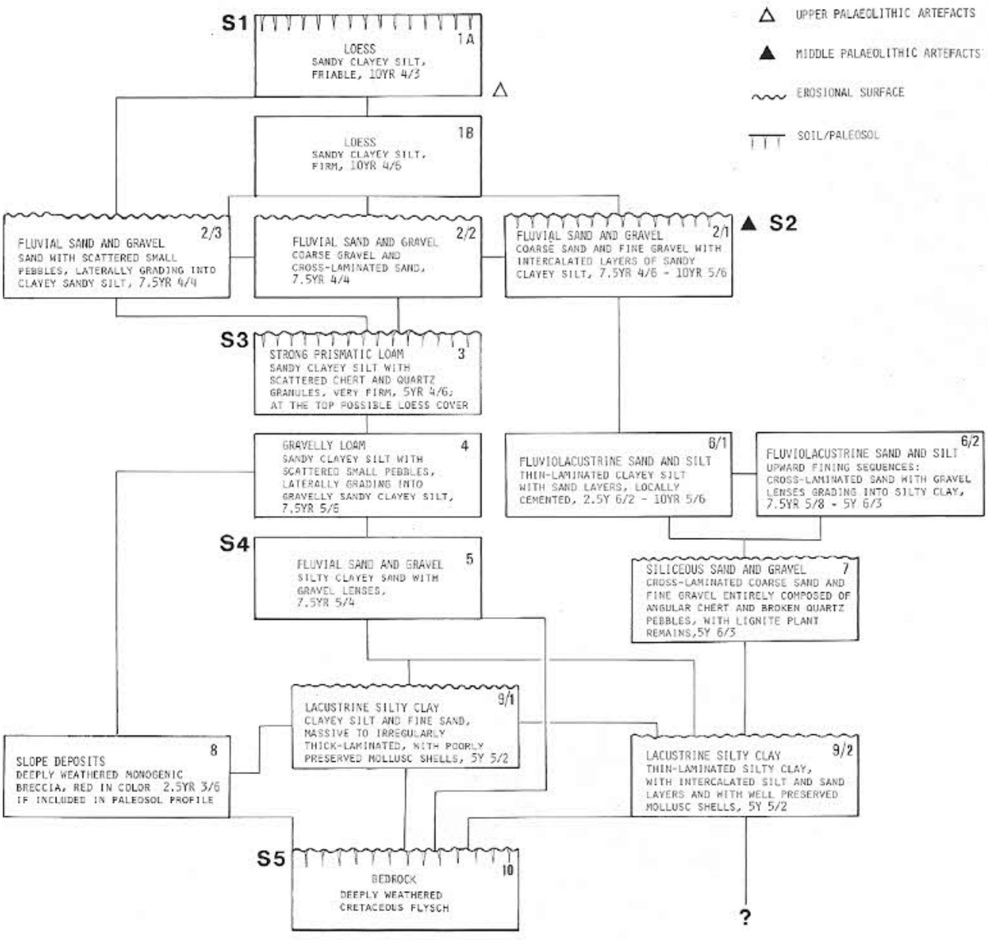

Fig. 4 – Stratigraphic scheme of the Bagaggera sequence (9/1 = 9A; 9/2 = 9B).

mum thickness 70 cm. In the section 8 numerous lignite plant remains are present (*Abies alba*, cf. Venzo, 1952, 1955). This unit is underlined by an undulating erosional surface.

8) *Slope deposits.* This unit crops out at the northern margin of the basin, directly overlying the bedrock in section 1, where it is represented by coarse angular clasts of sandstone of locale provenance, deeply weathered and dark red in color 2.5YR 3/6, being part of paleosol S4. The same layer laterally lowers and interfingers with unit 9A, becoming thinner and lighter coloured.

9) *Lacustrine silty clay.* This unit is present both in the northern sub–basin, where it lies directly on the bedrock, and in the southern sub–basin where the lower limit is not exposed. Two sub–units were differentiated. The lower one (9B) consists of laminated silty clay with thin silt intercalations and local sand lens–shaped beds. Overall color 5Y 5/2 light olive gray. Rare well preserved small mollusc shells are present. It crops out with a thickness of about 5 m in the southern sub–basin (but its thickness is possibly greater) and reaches, with reduced thickness, the northern sub–basin where it pinches out in sections 6 and 7. Here beds and laminae are dipping parallel to the basal erosional surface cut into the bedrock.

In the northern sub–basin a second sub–unit is present (9A) consisting of clayey silt and fine sand, locally laminated, 5Y 5/2, olive gray in color, about 3 m thick and with badly preserved mollusc shells. The lower boundary (exposed in section 6) is unconformable: the lower beds show a festoon structure inside a depression of the underlying sub–unit (9B) and pass upward to even parallel beds, with a gentle dip near the northern margin of the basin, where they interfinger with unit 8 (slope deposits).

10) *Bedrock.* The floor of the lacustrine basin is exposed in several sections (1, 2, 3, 6, 7). An irregular erosional surface cuts the local bedrock consisting of strongly weathered sandstones belonging to the Upper Cretaceous Bergamo Flysch.

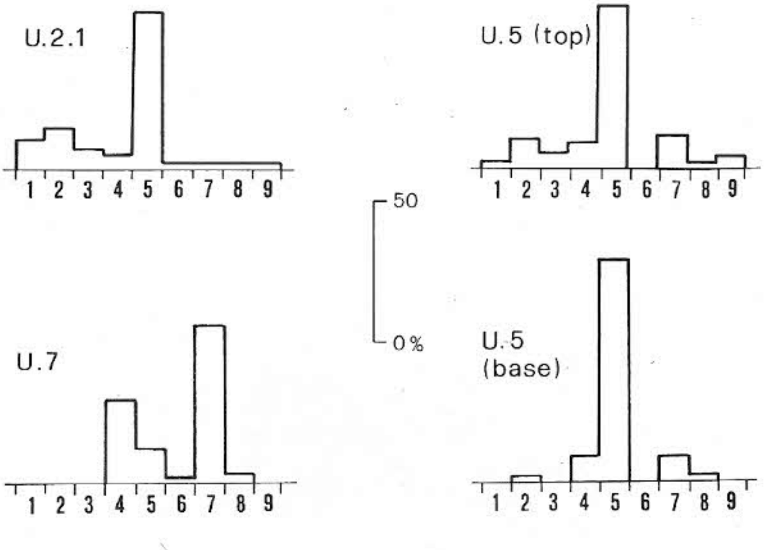

Fig. 5 – The petrographic composition of the gravel deposits of Bagaggera.
1) Granitic rocks; 2) Metamorphic rocks; 3) Quartzite; 4) Quartz; 5) Sandstones; 6) Volcanic rocks; 7) Chert; 8) Marly limestone; 9) Others.

2. 2. Petrographic and mineralogical composition: provenance of clasts and heavy minerals.

The possible sources for the sediments of the Bagaggera basin are:

1) the Bergamo Flysch bedrock and the fluvial deposits that dam the Curone valley (the Ceppo of Adda conglomerate, Paderno Member); 2) weathered gravels which are related to the Trezzo Member of the Ceppo of Adda; 3) the fluvioglacial deposits of Middle Pleistocene (Fig. 5 and 6).

The Bergamo Flysch consists of sandstone with carbonate cement, with pelitic interbeds and intercalations of conglomerate with well rounded quartz pebbles. The composition of the heavy minerals of the sand fraction (Tab. 1) of samples collected just in the vicinity of the Bagaggera basin is represented by prevailing garnet and ultrastable minerals (zircon and tourmaline), by an appreciable amount of epidotes and staurolite and subordinately by amphiboles, which are more abundant in the samples coming from the pelitic interbeds. Cipriani et al. (1976) have recorded a higher frequency of staurolite in samples

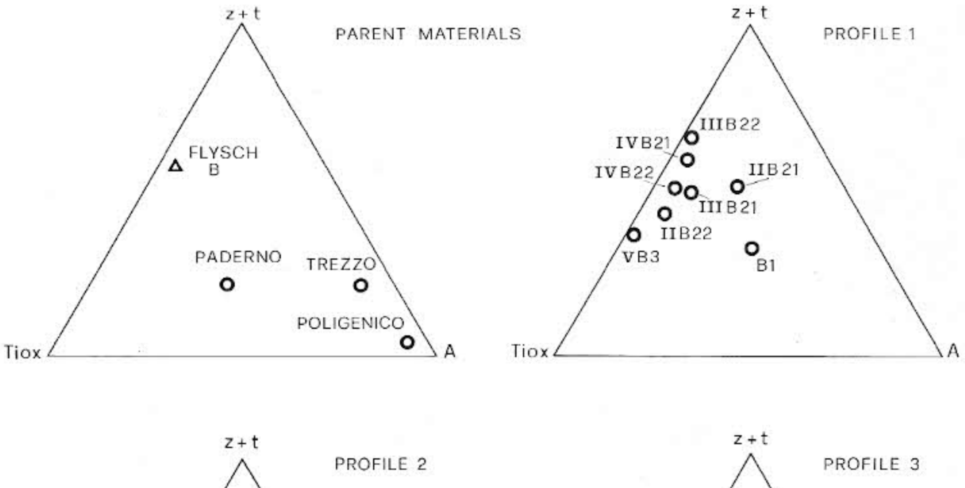

Fig. 6 – Diagrams of the composition of heavy minerals in the Bagaggera fill: z + t = zircon + tourmaline; Tiox = anatase + brookite, rutile, titanite; A = amphibole.

on the Bergamo Flysch of areas not close to the Bagaggera basin. Where the Flysch is weathered, the heavy minerals are represented only by Ti–oxides (anatase, brookite and rutile) and by the ultrastable minerals.

The conglomerate of the Ceppo of Adda, Paderno Member (Orombelli, 1979), consists exclusively of pebbles of limestone and calcareous sandstones. The heavy minerals association (Tab. 1, Fig. 6) is represented by prevailing garnets, an appreciable amount of epidotes, as well as amphiboles, Ti–oxides and staurolite, while tourmaline and zircon are rare.

The conglomerate of the Trezzo Member consists of a considerable amount of limestones and calcareous sandstones and of a subordinate amount of metamorphic, volcanic rocks and sandstones with siliceous cement. Among the heavy minerals (Tab. 1, Fig. 6) staurolite is prevailing, followed by amphiboles, garnets and epidotes, while the ultrastable minerals are subordinate.

The Middle Pleistocene fluvioglacial gravel (so called «ceppo poligenico») shows an extremely heterogeneous petrographic composition, due to the

	Ceppo Paderno M.	Ceppo Trezzo M.	Ceppo "Poligenico"	Bergamo Flysch
% 250–63μ	1.1	1.3	2.1	0.02
Zirc.	2	2	1	2
Tour.	6	4	2	15
Anat. + Brook.	12	2	2	9
Rut.	3	–	–	2
Tit.	+	–	–	+
Ep. + Zois.	23	16	12	15
Staur.	11	30	10	3
Garn.	27	17	20	52
Kyan.	+	4	2	–
And.	–	–	–	–
Chlor.	–	–	–	–
Sill.	1	5	2	1
Amph.	14	20	51	1
Glauc.	–	–	–	–
Pyr.	–	–	–	–

Tab. 1 – Heavy minerals, parent materials of the Bagaggera profiles.

occurrence of all the centroalpine lithotypes (granites, diorites, gneisses, micaschists, serpentinites). The heavy minerals of metamorphic paragenesis are largely prevailing, particularly amphiboles, followed by epidotes, garnet and staurolite, while tourmaline and zircon are definitely subordinate.

The filling of the Bagaggera basin shows a clear progressive change of the sources of its sediments (Tab. 2, 3, 4). The lacustrine deposits of the basal unit (U 9) bear a heavy minerals association similar to that of the Paderno Member of the Ceppo of Adda. As a consequence the lacustrine deposit can be thought of as marginal to the wide piedmont fans of the Ceppo. During this phase there is no appreciable supply from the slopes, which consequently, were stable, because covered by thick vegetation and subject to strong weathering. The fluvial sand and gravel (U 5) consist mainly of decarbonated sandstone; subordinate chert, quartz and metamorphic rocks are also present, but their percentage increases upwards (Fig. 5). The petrographic composition coincides considerably with that of the Ceppo of Adda, Trezzo Member. Also the heavy minerals com-

	B1	IIB21	IIB22	IIIB21	IVB21 t.	IVB21 b.	IVB22 t.	IVB22 b.	VB3	VC
%250–63μ	0.57	0.31	0.13	0.18	0.18	0.15	0.30	0.25	0.11	0.13
Zirc.	2	3	9	7	4	5	2	6	16	4
Tour.	12	25	18	22	30	25	29	38	26	40
Anat. + Brook.	5	7	18	11	11	11	15	17	37	44
Rut.	6	4	11	7	3	5	8	10	10	6
Tit.	1	3	3	5	3	3	3	9	10	5
Ep. + Zois.	40	34	32	36	39	23	33	19	–	–
Staur.	8	5	3	–	4	12	4	–	–	–
Garn.	6	1	–	–	+	+	–	–	–	–
Kyan.	4	3	2	5	1	3	3	–	–	–
And.	+	–	–	–	–	+	+	–	–	–
Chlor.	+	+	–	–	–	–	–	–	–	–
Sill.	1	2	–	1	2	2	+	1	–	1
Amph.	14	12	4	6	2	1	3	–	–	1
Glauc.	+	1	–	–	–	–	–	–	–	–
Pyr.	+	–	–	–	–	–	–	–	–	–

Tab. 2 – Heavy minerals, profile 1.

position with the prevalence of staurolite supports the petrographic affinity with this member.

From a petrographic point of view Unit 7 is very similar to the Paderno Member of the Ceppo of Adda. Nevertheless its clasts are represented by chert that come from dissolution of cherty limestones and by quartz pebbles that come from the conglomeratic layers of the Bergamo Flysch. The heavy minerals association is largely represented by the ultrastables and by the Ti–oxides. The residual nature of this unit is therefore evident: very likely it is the result of the erosion of a deep soil developed on the Flysch (S5, see chapter 3) and of a similar soil developed on the Ceppo of Adda at the Curone mouth. Furthermore the U5, like the U6, shows a composition of minerals that derives from the slopes of the Curone valley. Such situation in the southern sub–basin lasts till the end of the fluviolacustrine sequence. Nevertheless one can observe in these deposits a progressive enrichment of minerals of metamorphic paragenesis that

	Ap	B1	IIB21	IIB22	IIIB21	IIIB22	IIIC1	U.6t	U.6b	U.7	U.9
%250–63μ	1.24	1.44	0.93	0.58	0.35	0.71	0.54	0.22	0.18	0.47	0.11
Zirc.	1	2	+	–	1	3	1	7	8	8	–
Tour.	7	8	10	16	14	12	15	14	20	12	6
Anat. + Brook.	5	1	3	1	6	6	–	18	19	13	5
Rut.	+	1	2	+	3	1	5	10	12	9	3
Tit.	+	–	+	2	2	2	+	7	1	+	–
Ep. + Zois.	31	44	41	40	41	46	35	16	31	12	21
Staur.	+	1	4	6	8	13	32	21	2	2	2
Garn.	2	2	+	–	+	–	–	–	3	43	35
Kyan.	1	–	3	1	+	3	4	–	–	+	2
And.	–	–	–	–	–	–	–	–	–	–	2
Chlor.	–	1	1	+	+	–	–	–	–	–	–
Sill.	1	1	3	6	2	2	3	+	+	+	–
Amph.	51	39	33	28	23	12	1	3	3	1	16
Glauc.	–	+	–	–	–	–	–	–	–	–	–
Pyr.	1	+	–	–	–	–	–	–	–	–	–

Tab. 3 – Heavy minerals, profile 2 and lacustrine sediments.

become prevailing in the loess at the top of the sequence. In the northern subbasin the metamorphic minerals, particularly the epidotes, prevail over the ultrastables. The gravels of U2 consist mainly of sandstones, but they have an appreciable amount of crystalline rocks, as granites and metamorphic rocks, that can be perfectly correlated with the petrographic composition of the Middle Pleistocene fluvioglacial deposits. The above observations are synthetically represented in the diagrams of Fig. 5, 6. On the diagrams relative to the heavy minerals, the vertexes represent the percentages of zircon and tourmaline (z + t), anatase + brookite + rutile (Tiox), which are minerals peculiar of the sediments coming from the slopes of the Curone valley that underwent pedogenesis, and the sum of amphiboles and glaucophane (A) that characterize the sediments of centroalpine origin.

The petrographic trend, already known for the Paderno d'Adda sequence, is confirmed also in the Bagaggera sequence, with a few differences due to the different nature of the sedimentary environment.

	IVB23t	VB21	VIB22t	VIB22t 3	VIIB21t U4	VIIIB2 U5
%250–63μ	0.17	0.92	0.78	0.90	0.30	0.25
Zirc.	3	3	2	2	4	3
Tour.	8	13	15	7	19	4
Anat. + Brook.	3	13	8	6	10	7
Rut.	1	3	3	2	6	3
Tit.	–	1	1	2	–	–
Ep. + Zois.	43	45	49	43	35	22
Staur.	32	9	11	28	16	47
Garn.	–	1	+	–	2	2
Kyan.	2	5	2	3	4	5
And.	1	–	–	3	–	+
Chlor.	1	–	+	+	–	–
Sill.	4	2	1	+	2	5
Amph.	1	4	+	4	2	1
Glauc.	1	1	–	–	–	–
Pyr.	–	–	–	–	–	–

Tab. 4 – Heavy minerals, profile 3.

3. Paleosols. (M. C.).

Well preserved and well exposed paleosols are present in the Bagaggera clay pits. Their characteristics and distribution are significatively related to the morphology of the basin and to the different sedimentary facies of the fill.

Three pedological sequences have been studied. Profile 1: polygenetic paleosol developed on slope deposit (S1 + S2 + S3 + S4) covering a buried paleosol on the Flysch bedrock (S5). The profile is characteristic of the northern margin of the basin where sedimentation rate was low and soil development or erosional phases prevailed. Profile 2: paleosol on fluviolacustrine sediments, buried by loess; it is characteristic of the basin South of the threshold where sedimentation largely prevailed and soil forming processes took places only after the complete fill of the basin. Profile 3: buried and polygenetic paleosols, separated from one another by more or less weathered sediments. The profile is characteristic of the basin North of the bedrock threshold, and indicates

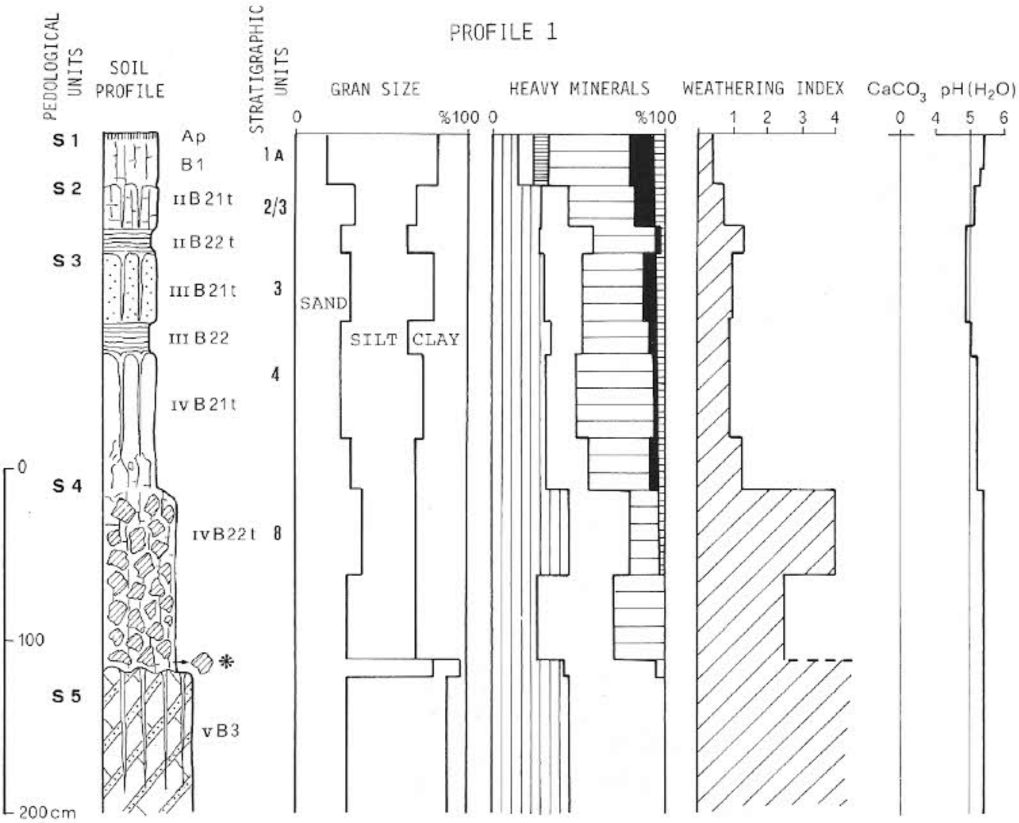

Fig. 7 – Paleosol profile 1, along section 1. Heavy minerals, from left: zircon + tourmaline, Tiox, garnet, epidote + zoisite + staurolite, amphiboles, others.

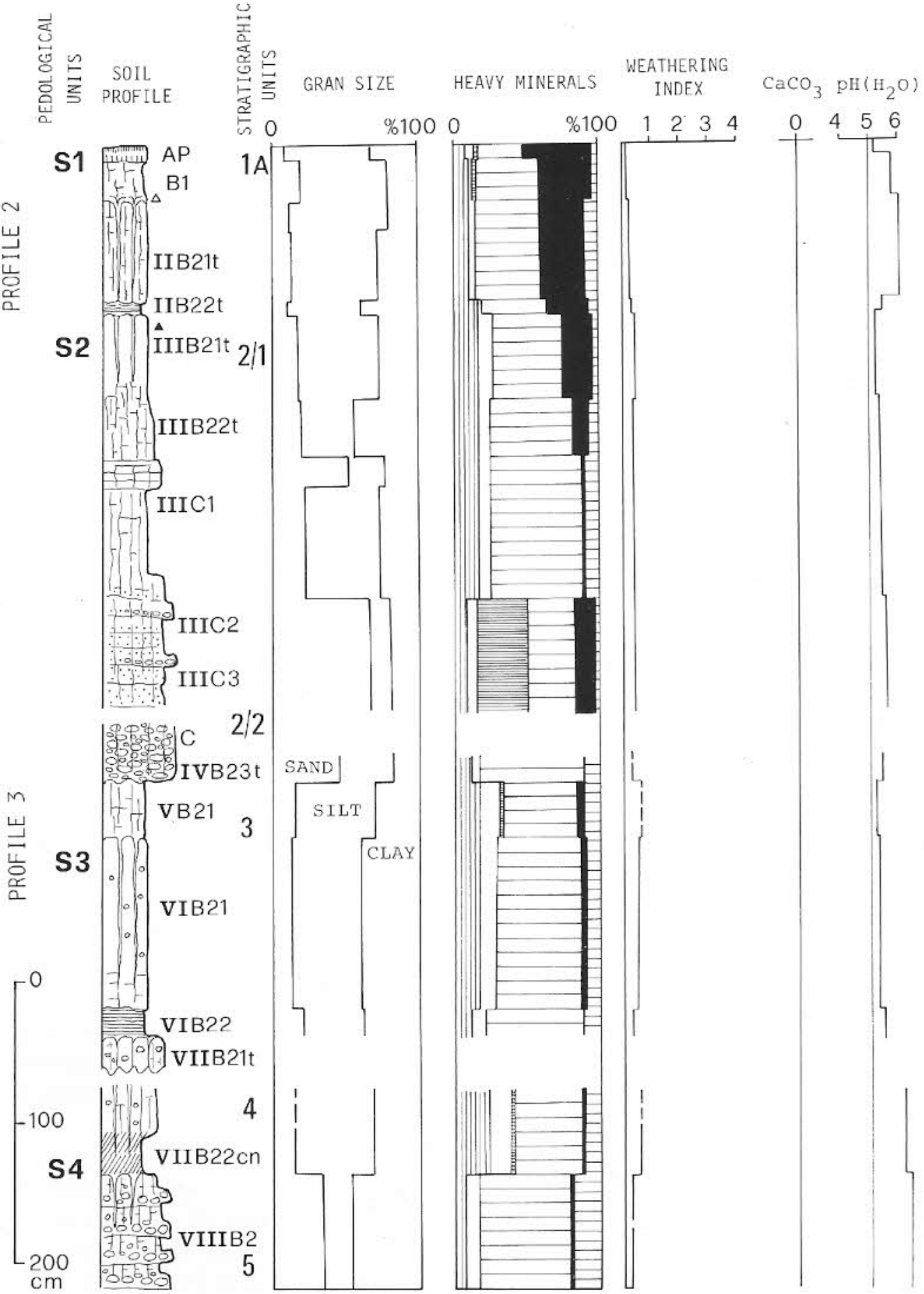

Fig. 8 — Paleosol profiles 2 and 3, along the sections 4, 6 and 9.

alternanting phases of pedogenesis and fluvial/fluvioglacial sedimentation.

The detailed descriptions are exposed in Appendix I, short micromorphological descriptions in Appendix II, chemical, textural, heavy minerals analysis are synthetically represented in Fig. 7, 8.

The soil developed on loess (S1) in the profile 2 (Ap, B1, IIB21tx, IIB22t) can be classified, according to the Soil Taxonomy (Soil Survey Staff, 1975) as *fragic glossudalf, sol lessivé glossique à fragipan* according to Duchaufour (1977).

Clay illuviation, development of whitish tongues and slight hydromorphy are due to Holocene weathering. The same processes and very similar pedologic characters are recorded in loess soils in France (Jamagne, 1973) and Holland (Bouma et al., 1968).

Upper palaeolithic artefacts lying on a unique level, at the contact between horizons B1 and IIB21tx suggest the presence of a buried surface, just at the top of the fragipan. The formation of a fragipan in loess soils (Fitzpatrick, 1956; Van Vliet & Langoror, 1981) is commonly related to the presence of permafrost during glacial periods. In IIB21tx horizon fluidal microstructures (Appendix II) can be related to cryogenic origin.

On the other hand, Smalley & Davin (1982) state that fragipan in loess could be due to slightly developed soil, buried by a fresh loess cover.

In Bagaggera profile archaeological evidence proves that the surface, just above the fragipan, has been inhabited by Palaeolithic hunters and therefore was exposed for some time before the deposition of a new loess cover. Some charcoals of *Pinus* and *Betula*, associated with the artefacts, indicate that the environment, when the surface was exposed, was very cold: and therefore occurrence of periglacial phenomena, as seasonal frost, cannot be excluded. Therefore both periglacial model and buried soil model could explain the formation of fragipan in Bagaggera.

Paleosols S2, S3 and S4 in the profiles 2 and 3 are buried paleosols whose development has been interrupted by erosion and by subsequent aggradation of the overlying sedimentary bodies.

Even if burial has never completely prevented the paleosols from being affected by the subsequent soil forming processes, nevertheless they have not substantially changed their peculiar characteristics and, consequently each of them should represent a distinct pedogenetic phase.

The three paleosols have similar parent material, consisting of fluvial or fluviolacustrine sediments, fine and coarse interbedded and originally containing carbonates. Furthermore they show similar pedogenetic characteristics, equally developed as far as type and intensity are concerned. Carbonates have been deeply leached: the leaching front, in the profile 3 is 13 m deep, much below the «solum». The rubefaction is moderately developed: the Hue of the

B horizons ranges from 7.5YR to 5YR. Clay translocation is the most evident pedologic process of these soils: fine textured horizons show strong sepic fabric and very thick compound ferriargillans occur in coarse textured horizons. Ferri-argillans are very frequently interbedded with coarse cutans (siltans, matrans, scheletans). However that features are not exclusive of the Pleistocene paleosols but occur in S1 too, which developed during the Holocene. Mottling, Fe–Mn nodules, and occurrence of grainy cutans, indicate temporary hydromorphic conditions in almost all horizons.

Paleosols S1, S2, S3, S4 show pedological features, whitish tongues, laminated horizons, and accumulations of ferrimangan nodules and concretions, which deserve a particular comment, because they have been often used in defining the stratigraphy of the paleosols in the Northern Lombard plain (Billard, 1974, 1977, 1980).

The laminated horizons of Bagaggera are sometimes thicker than 10 cm, they have a greater clay content (Fig. 7, 8), but the same mineralogical composition as the overlying horizons and consist of alternating mottled laminae of illuvial clay and loam. By a micromorphological point of view, clay laminae are the result of the accumulation of thick well ordered argillans alternating with siltans and loam laminae have sepic fabric and dont show evidences of cryogenic disturbances.

The laminated horizons, always show pseudogley features and laterally grade into horizons particularly rich in Fe–Mn concretions and nodules, that are generated in correspondance with perched aquifers developed in textural discontinuities (Van Schuylenborg, 1973; Bini et al., 1978; Duchaufour, 1977). Laminated horizons of the Bagaggera paleosols seem therefore to be the result of the accumulation process of illuvial clay (Dijkerman et al., 1967; Soil Survey Staff, 1975) in correspondance of vertical lithologic variations and pedological discontinuities.

White tongues are not found exclusively in the fragipan of the S1, but they are also present in the B horizons of the other soils, even when these ones do not show texture and consistance such as to be defined fragipans.

There is a general concordance between the Authors on the mechanism of formation of tongues, which generate along the structure of the B horizons. In fact the fractures, during the humid seasons, become the preferential path for the percolating waters that create reducing conditions which cause bleaching of the crak walls (Bouma et al., 1968; Soil Survey Staff, 1975).

In the opinion of Billard & Fedoroff (1977) and Billard (1980) the development of white tongues in the Northern Italian paleosols is due to the degradation of interglacial *lessivé* soils under cold climate at the beginning of a glacial period.

In Bagaggera tongues occur systematically in the B2 horizons of the soil on loess S1, which is of Holocene age and in paleosols S2, S3, S4. They are strongly developed in the polygenetic paleosol of the profile 1 and, on the contrary are weackly developed on the buried S3 paleosol in profile 3; its development therefore seems related to the permanence of paleosols near the surface.

On the whole, the formation of tongues seems a normal continuation of the process of clay illuviation under humid climate.

At the top of the S2 paleosol Middle–Lower Palaeolithic artefacts (see cp. 4) have been collected; although their age is not exactly known, they indicate that paleosol S2 was already developed in early Würm or Eemian interglacial period.

On the other hand, paleosols S2 and S3 show direct paleomagnetic polarity and therefore they date back to Middle Pleistocene; on the contrary paleosol S4 shows clear reversed polarity, consequently it developed during Matuyama period, in Early Pleistocene.

Comparing S2, S3 and S4 paleosols with present–day soil taxonomies, they can be referred to the *Sols lessivés glossiques* in French classification (Duchaufour, 1977); following the Soil Taxonomy of the Soil Survey Staff (1975), they show close affinities with the Great Group of the *Glossudalfs*, or in the FAO System (Fitzpatrick, 1980), can be regarded as *Podzoluvisols*. According to these classifications, the paleosols developed under deciduous forest in a humid temperate climate with important seasonal soil moisture contrast.

In the profile 1 four distinct units can be recognized: 1) Ap+B1: colluvial loess, lying on a erosional surface; 2) IIB21t, IIB22t, IIIB21t, IIIB22, IVB21t: loamy slope deposits weathered in strongly developed argillic horizons; they can be correlated with S2 and S3; 3) IVB22t: loamy slope deposits weathered in strongly developed B argillic horizons, including clasts of the monogenic breccia (U8) which are large pedorelicts of the paleosol developed on the flysch bedrock; 4) VB3, VC: weathered bedrock. Units 2–3 are a part of the same poligenetic soil, in which the interfingering of several generation of ferriargillans and coarse cutans, and the progressive change of magnetism from reverse in the lowermost layers to direct (see cp. 5) suggest that the pedogenetic phases, which elsewhere in the basin have generated S2, S3, and S4 paleosols are here interpenetrating.

The buried paleosol developed on the Flysch (S5) shows peculiar characteristics. From the stratigraphic point of view it is separated from the following paleosols by an important erosional phase, by the sedimentation of the lacustrine units (U9) and by the deposition of the *monogenic* breccia.

The paleomagnetic stratigraphy and the stratigraphic context indicate that these events took place during a long time interval that can range from Early Pleistocene to part of Pliocene. The S5 paleosol shows only a few metres of horizon B that originally was certainly much thicker. The upper part of this horizon is testified by the pedorelicts of the *monogenic* breccia. About 18 meters of decarbonated friable Flysch (saprolite) are present at the margin of the basin below the B horizons preserved in situ. The carbonated Flysch outcrops at the base of this saprolite in shape of core stones. Laterally, in the center of the basin, saprolite grades into a thick horizon with wide mottles, and discontinuous bands cemented by silica.

The mineralogy and micromorphology (Fig. 8, Appendix II), of the B3 horizon of this soil suggest a picture of strong weathering: among the primary minerals, only quartz, some micas, tourmaline, zircon and Ti–oxides are preserved. Among the clay minerals a slightly increase of disordered kaolinite can be observed (Tab. 5).

From the micromorphological point of view the plasma consists mainly of red oxides (haematite) and clay minerals, is isotic or only slightly birefrigent. There are no evidences of an argillic horizon, being the clay coats poorly developed or strongly weathered and mainly present in the lower C horizons, along the fractures and the bedding joints of the Flysch.

The paleosol S5 on the whole seems to be the result of strong «intertropical» weathering, and have oxic features by a micromorphological point of view (Stoops, 1982). On the contrary mineralogical and chemical characters dont reach the requirements for ferrallitic process (Soil Survey Staff, 1975; Duchaufour, 1977; Fitzpatrick, 1980).

Therefore paleosol S5 cannot be easily classificated in present day soils taxonomies, however it can be regarded as intermediate between *Ferrisols* (Duchaufour, 1977) and *Oxisols* of Soil Taxonomy (Soil Survey Staff, 1975).

Horizon	18 A°	14 A°	10 A°	7 A°
B1	–	X	XX	X°
IIB21t	(X)	X	XX	(X)
IIB22t	–	tr	XX	(X)
IIIB21t	X	X	XX	(X)°
IIIB22t	X	(X)	XX	tr°
IVB21t	–	tr	XX	X°
IVB22t	XX	X	XX	XX°
VB3	X	(X)	XX	XX°

Tab. 5 – Bagaggera, profile 1: X–ray analysis on fine earth (tr = trace; (X) = very weak reflections; X = weak reflections; XX = moderately strong reflections; ° = broad reflections).

4. Palaeolithic finds. (M. C.).

Two distinct lithic assemblages have been found in different stratigraphic positions in the Bagaggera sequence.

The first one consists of several hundreds of chert artefacts lying on the buried surface between two loess covers (Unit 1A and 1B). Cores and flakes deriving from core reduction are largely dominant while formal tools are much rarer. Locally they show the characteristic abrasion due to the friction of loess particles. Thermal detachments from some artefacts and few charcoals indicate the presence of hearths.

Representative artefacts are sketched in Fig. 9; they are ascribed to the Upper Palaeolithic (Epigravettian).

The second group, less numerous, has been found in Unit 2, in the upper part of the IIIB21t horizon. These artefacts are not reworked but a whitish patina and reddish clay coats indicate that they underwent the soil forming processes of the S2 paleosol.

Unfortunately too few artefacts have been found up to now, so that it is not possible to determine what Palaeolithic industry they belong to. The recovered tools (a point and a latero–transversal scraper) as well as the rare flakes may ascribe the industry to a Mousterian of non Levallois technique.

5. Palaeomagnetism. (J.C.S.).

Palaeomagnetic investigations were carried out on samples from the lacustrine and fluviolacustrine sediments of the southern sub–basin, and from the weathered profiles developed on the various units of the northern sub–basin. In each case the aim of the study was to define a characteristic magnetization which could be used to date the deposits.

The characteristic magnetization of lacustrine and fluviolacustrine sediments forms through alignment of grains, usually of magnetite, already possessing a magnetic remanence. The grains rotate so that their remanence direction is parallel with the ambient field as they fall through water, and are able to continue rotating in response to any field changes after deposition if there is sufficient water content in the pore spaces. This detrital remanent magnetization (DRM) will be "locked in" when the grains are prevented from further movement either by reduction of the pore space by compaction, or by increased surface tension due to dewatering. Thus the magnetization forms at a small depth below the sediment–water interface, and is characteristic of the ambient geomagnetic field shortly after deposition.

The characteristic magnetization of a paleosol is a chemical remanent magnetization (CRM) formed through the growth of grains in a magnetic field. Alteration of magnetite will lead to the oxidation of ferrous iron to ferric iron,

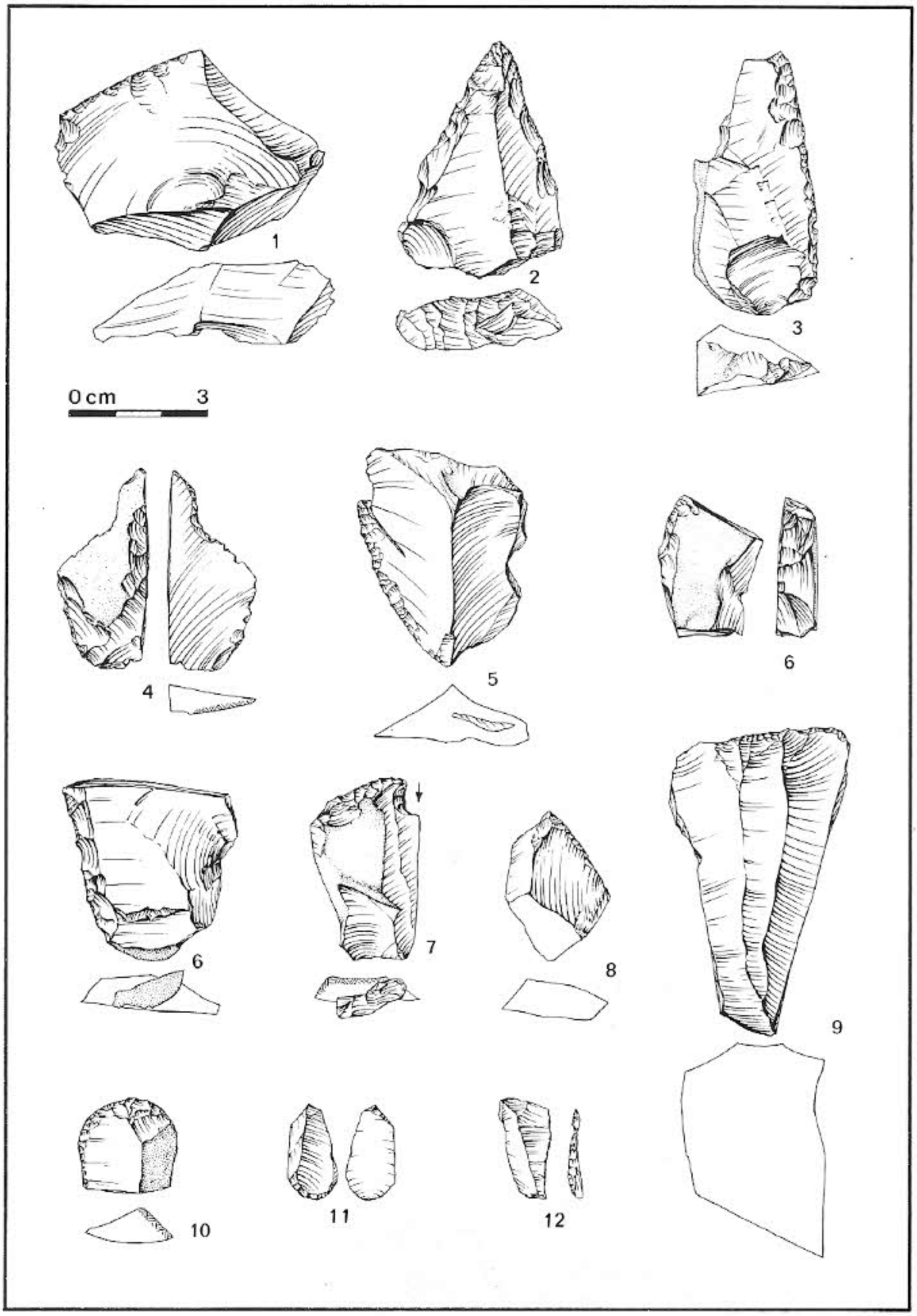

Fig. 9 — Palaeolithic artefacts found in the section 9. Mousterian (?) artefacts (1, 2, 3) from the top of the stratigraphic unit 2. Upper Palaeolithic artefacts (4–12) from the base of the stratigraphic unit 1A.

which will be precipitated as haematite, giving the deposits a characteristic red colour. As the grains grow through a critical blocking diameter, estimated to be about 0.1 μm (McElhinny, 1973), they acquire a stable remanence. In the weathered profiles of the northern sub–basin the alteration has been very intense, probably removing the magnetite completely, so the characteristic magnetization dates from the period of weathering. In deposits where the alteration has only been slight the two magnetizations (DRM and CRM) will give a blurred signal, especially if they were formed during different magnetic epochs.

5. 1. Sampling and measurement.

Samples were taken at intervals of 1–5 cm from the lacustrine and fluviolacustrine clays and silts of sections 8 and 9. Bucha & Sibrava (1977) reported the occurrence of a polarity reversal in Unit 9 at a profile similar to section 9 (Billard et al., 1982). The reversal occurs very close to a vertical change from grey silty clay to oxidized brown silty clay. At section 8 the oxidation is not seen in Unit 9, perhaps because downward percolation of water was prevented by the above lying clay layers of the Unit 6. Palaeomagnetic investigation of both sections was undertaken to determine whether the reversal is real, or if was caused by superimposition of a chemical remanence at a later date.

Samples were also taken from the matrix of weathered profiles developed on Units 1 to 8 and on the Flysch bedrock in the northern sub–basin (Fig. 3). The lacustrine clays at the base of section 6 were also sampled.

All of the samples were measured on a cryogenic magnetometer at the University of Edinburgh, which has a noise level equivalent to a sample intensity of between 0.01 and 0.1 μG. Pilot samples from each unit were demagnetized stepwise in an alternating field to determine the optimum field for blanket demagnetization of the remaining sample.

5. 2. Results.

5. 2. 1. *Northern Sub–basin.*

The natural remanent magnetization (NRM) of samples from the paleosols varies in intensity from 10 to 100 μG, although intensity in the flysch of section 1 is slightly lower (between 1 and 2 μG). Susceptibility lies between 10 and 100 μG/Oe, giving G–ratios (i.e. intensity susceptibility) of almost 1. The clays of unit 9 in section 6 have lower intensities (0.1 to 1.0 μG) with susceptibilities of slightly less than 10 μG/Oe giving lower G–ratios.

Most samples from the weathered profiles are stable, changing little in direction with demagnetization, however hardness varies considerably: median destructive field varies from about 115 Oe (BL2) to over 600 Oe (BL7').

Samples from the bottom part of section 6 show larger changes in direction with demagnetization, BL16 appears to have a moderately stable normal magnetization, however BL12' becomes intermediate in direction at 200 Oe, accompanied by a rise in intensity. In both cases the initial remanence is low ($< 0.5\ \mu G$) so the directions may be masked by instrument noise.

After blanket demagnetization at 150 Oe, the samples of section 1 showed little change in intensity reflecting a hard magnetization as seen in sample BL7'. This behaviour is characteristic of haematite which is resistant to alternating field demagnetization. Most of the samples from section 1 are normal, however one sample from Unit 8 has a low negative inclination. This may be due to alteration during a reversed epoch, or it may represent the primary remanence of a fallen block. The remanent directions in the flysch below are more consistent with stable normal polarity before correction for dip, suggesting that the alteration that gave rise to the magnetization in these rocks occurred after folding.

Samples from Units 1, 2 and 3 in section 6, and Unit 4 in section 4 have normal inclination, probably representing alteration during a normal epoch, although one sample (BL27) at the base of Unit 3 has a southerly declination, giving an intermediate virtual geomagnetic pole (VGP) latitude. Unit 5 is represented in section 4 by two samples, both with reversed inclination, one with southerly declination, suggesting that the paleosol on Unit 5 (S4) formed during a reversed epoch.

Samples from the lacustrine clay in section 6 have mainly normal inclination, however there is much scatter in declination, probably due to low intensity. Two samples from the flysch are reversed. These differ in strength (NRM $< 0.1\ \mu G$) and in direction from the flysch in section 1, so they may represent a different, less intense period of alteration, or they may reflect the original detrital remanence of the flysch.

5. 2. 2. *Southern Sub–basin.*

Section 8. NRM intensity in the clays of Units 6 and 9 averaged $4.5 \pm 4.9\ \mu G$. The lowermost 150 cm of Unit 6 have lower intensity compared with the top of this Unit and Unit 9; this low is also seen in susceptibility indicating that there was a reduction in magnetic mineral content during this interval. Susceptibility averages $7.5 \pm 3.3\ \mu G/Oe$ throughout the section giving Q–ratios of about 0.6 (Fig. 10).

Pilot demagnetization demonstrated that most of the samples possessed a stable remanence, carried by grains with a range of coercivities. Median destructive fields are generally between 300 and 500 Oe, however occasional samples at the top of the section, and near the transition are softer (e.g. BG 5' at 25 cm, and BG80" at 391 cm). Reversed samples do not show the presence of a normal overprint resulting from viscous remanence (BG77': 441 cm). Most samples show no change in direction apart from the development of a spurious magnetization at 400 Oe or above. Samples in the transition zone show a small amount of movement: BG84' (399 cm) change from normal directions to intermediate directions, the softer component representing a younger magnetization.

After blanket demagnetization, intensity has been reduced by only 7% to an average of 4.2 μG, and shows a pattern similar to that seen at NRM. The lowermost samples are reversed, showing a fair degree of scatter. A reversed to normal transition occurs between 404 and 393 cm, above which samples are normal apart from an excursion at 367 to 368 cm, coinciding with Unit 7. The results show a large amount of scatter between the transition and about 2.40 m, above which there is little variation.

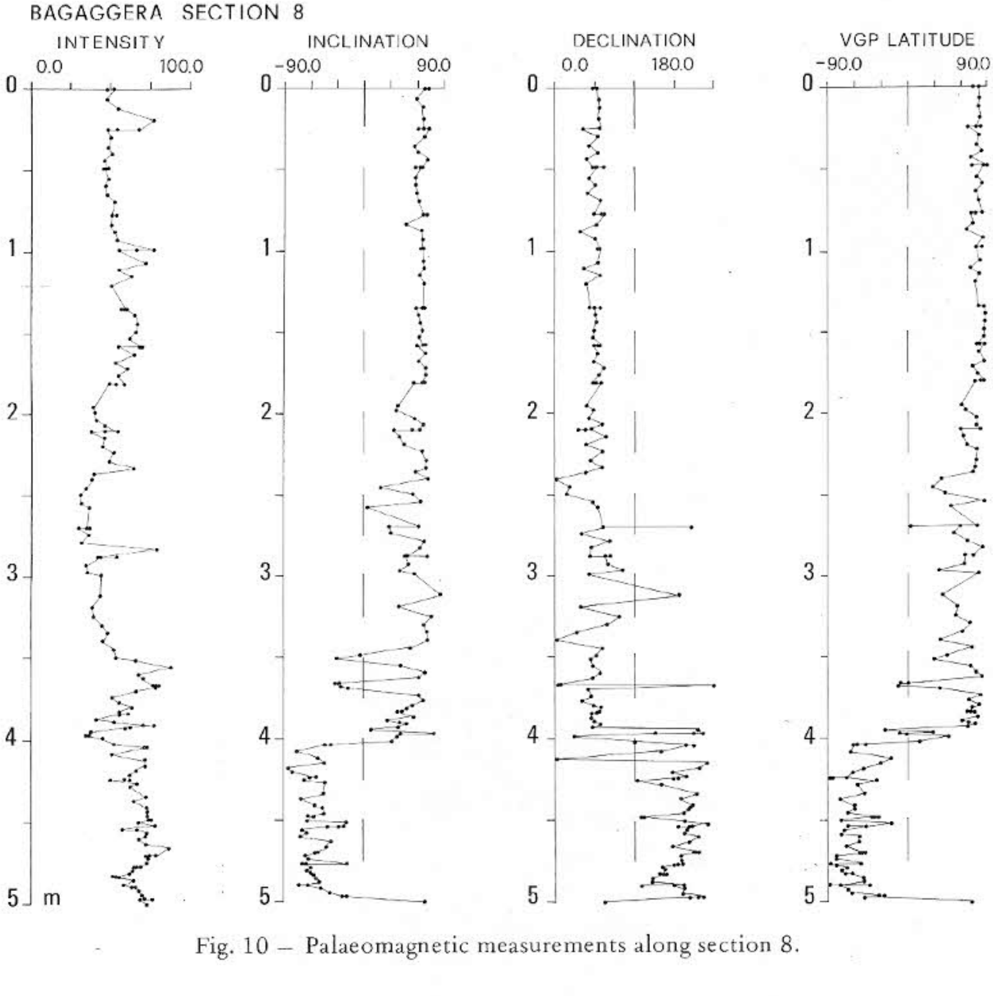

Fig. 10 — Palaeomagnetic measurements along section 8.

Section 9. Intensity shows a step in values coinciding with the first visible signs of oxidation at 113 cm (more complete oxidation is seen above 98 cm). Below the step intensity averages 4.6 ± 3.3 μG, above 113 cm average intensity drops to 0.2 ± 0.1 μG. Susceptibility is only slightly lower above 113 cm but not significantly so, the average throughout the section is 7.9 ± 1.8 μG/Oe. Low values are seen between 98 cm and 113 cm, reaching a minimum of 3.4 μG/Oe at 103 cm. G–ratios reflect the step seen in the intensity curve, averaging 0.5 ± 0.4 in the blue clays, and 0.03 ± 0.02 in the brown–orange clays (Fig. 11).

The direction of the natural remanence shows a marked change coinciding with the change in intensity at 113 cm. Inclination is mainly reversed below this averaging −39.4 ± 15.1; between 113 cm and 107 cm inclination becomes normal, and averages 45.1 ± 23.4 in the upper part of the section, although low inclinations are seen between 93 and 97 cm. Declination is reversed below 113 cm, most values lying to the West of South. Above 113 cm the scatter of values becomes much greater, with rapid oscillation between normal and reversed directions. Virtual geomagnetic pole (VGP) latitudes for the NRM directions reflect the step in inclination, changing in general from southerly latitudes to

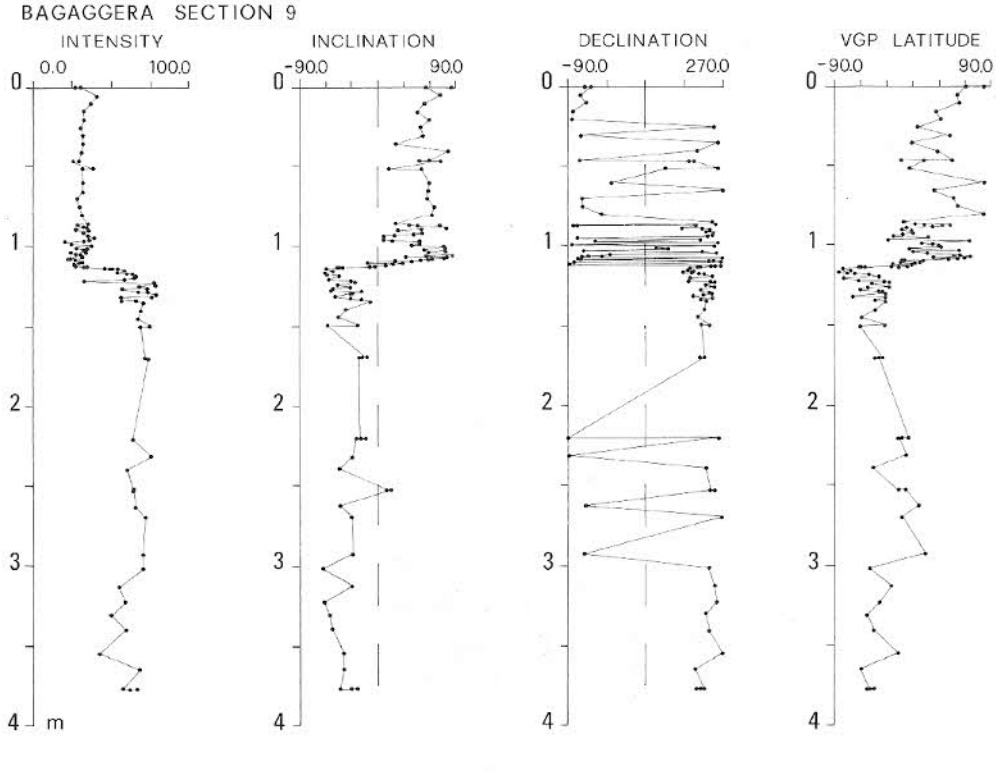

Fig. 11 — Palaeomagnetic measurements along section 9.

northerly latitudes, however the pole does not reach high normal latitudes in the upper part of the section, and show a large amount of scatter.

Demagnetization characteristics can also be classified into two groups: those of oxidized and unoxidized samples. Below 113 cm samples are generally stable, with little or no change in direction, and median destructive fields of between 240 and 590 Oe. Sample B42 (115 cm) shows a slight increase in intensity up to 100 Oe, which is indicative of a normal viscous remanence superimposed on the reversed primary remanence. In the oxidized clays, low intensity causes larger scatter in directions between demagnetization steps because of the relative increase in noise. The samples generally change direction between 0 and 150 Oe, then remain more or less stable (e.g. B46 at 111 cm and B66 at 91 cm). Intensity sometimes decreases between 0 and 150 Oe if a change in direction occurs. After 150 Oe there is very little change in intensity (compare B44 at 113 cm with B43 at 112 cm). Median destructive fields are generally either lower than 150 Oe (B58 at 99 cm) or greater than 600 Oe (B44). The general trend for this upper set of samples is toward a direction with low inclination and usually southerly or southeasterly declination.

The directions after blanket demagnetization show a step in inclination at 113 cm as at NRM, but while the lower samples have a similar value to NRM ($-39.9 \pm 16.3^\circ$) the upper samples have decreased to $21.5 \pm 18.7^\circ$. Declinations are mainly between 180° and 270° throughout the section giving VGP latitudes of -60° to -30° in the lower part, and -30° to 0° in the upper part. The decrease in intensity after blanket demagnetization is proportionally greater in the upper part of the section (35% compared with 10%) indicating that a greater percentage of the remanence in the oxidized samples is carried by grains with low coercivities.

The palaeomagnetic history of section 9 at Bagaggera can be interpreted as follows. The lowermost 2.87 m of blue–grey clay were deposited at a time of reversed polarity, recorded by the natural remanence. The clay above a depth of 113 cm was deposited during a polarity transition and during the period of normal polarity which followed. The initial remanence was probably carried by similar grains to those in the lower part of the section. Some time after deposition the upper 113 cm of the section were subjected to chemical alteration resulting in the formation of a chemical remanent magnetization. The alteration preferentially attacked the smaller grained magnetite, giving rise to haematite as shown by the colour of the section which is blue–grey below 113 cm and brown–orange above and the coercivity spectrum of NRM which changes with the removal of a component whose coercivity is represented by alternating field demagnetization between 200 and 600 Oe, and its replacement by a component still present above 600 Oe. In addition hysteresis experiments show that S value as defined by Stober & Thompson (1979) shows a decrease above 113 cm which is indicative of haematite in the oxidized clays (Salloway, 1983). Demagnetization of these oxidized samples involves a change in direction from normal to intermediate between 0 and 150 Oe, usually with a drop in intensity. The initial drop in intensity is due to the removal of a normal component carried by less finely grained magnetite, which is not greatly affected by oxidation (susceptibility, which generally reflects the amount of larger grained magnetite is more or less constant above and below the level of oxidation). This normal vector is probably a primary remanence similar in nature to that seen in the lower half of the section. The intermediate directions carried by the haematite imply that the oxidation took place when the ambient field was other than normal. The directions may represent the true field at the time of oxidation, in which case the field was either partly through a reversal, or undergoing an excursion. Alternatively the directions represent a mean between the ambient field direction and the primary remanence recorded before alteration, in which case the ambient field may have been stable and reversed. When difference vectors are calculated for the oxidized samples, for the component removed up to 150 Oe, the inclinations are high and positive and, although declinations are scattered around North (largely due to the increased error involved in finding difference vectors), the VGP latitudes above 113 cm are positive.

Bucha & Sibrava (1977) were able to sample a more extensive section near section 9, including unit 6 above the erosion surface which forms the limit of sampling for this work. From their figure 2 it would appear that directions in this part of the section are consistently normal, suggesting that the reversed oxidation is not present in these deposits. If this interpretation is correct at least two periods of alteration have occurred, the former taking place in a reversed epoch, before deposition of Unit 7. This does not explain the absence of oxidation in the lower part of section 8, so perhaps the erosional and weathering history is more complex than appears at first sight.

5. 3. Transitional paths.

The age of the transition recorded in sections 8 and 9 must be at least 730,000 years, the age of the Matuyama–Brunhes transition (Mankinen & Dalrymple, 1979). The presence of reversed oxidation above the transition suggests that this reversal may be the base of the Jaramillo Event (970,000 yr. B. P.) or older. In an attempt to date the transition its fine structure has been studied so that this can be compared with other transition paths from nearby locations. Hillhouse & Cox (1976) have shown that the transitional field is not dipolar, however it may be dominated by low order zonal harmonics, e. g. quadrupole or octupole fields (Hoffman & Fuller, 1978). This would give a similar transitional field at sites over an area the size of Central Europe. Hoffman (1979) published a type path for the Matuyama–Brunhes transition in Europe based on the site of Bruggen in West Germany, studied by Koci & Sibrava (1976). This consists of an excursion of the VGP to India, followed by a reversal through the Atlantic. However this section probably represents an older transition, possibly the base of the Olduvai Event at 1.87 Ma. (Koci, pers. comm.). The transitional path for the Matuyama–Brunhes reversal probably passed through Australia and Eastern Asia, as shown by data from a number of European sites typified by Stranska Skala (Koci & Sibrava, 1976) and Tiepido in Italy (Salloway, 1983). A transition from Stirone which probably represents the Lower Jaramillo transition is also shown in Salloway (1983). This path is mainly confined to the Atlantic.

The record of the transition at section 9 is confused by the reversed overprint. At NRM the path passes northward through South America and the Western Atlantic, with a lot of variation in the second half of the transition. When demagnetized the directions give VGP clustered around the South American continent, never reaching high northerly latitudes. In an attempt to improve the resolution difference vectors were calculated for the component of the natural remanence removed up to 150 Oe. These results suggest that the transition took place between samples B43' (114 cm) and B44' (113 cm). The nature of the transition zone cannot be clearly decided from the results of section 9, but there is a suggestion of bias towards South America.

The results from section 8 probably represent a much more accurate record of the ambient field during the transition (Fig. 12). The pole moves first towards India (BG85, 402 cm) then across to the Caribbean and the South Atlantic (BG 84 to BG82: 399–395 cm), and finally through North America to Alaska (BG 81 at 393 cm). Three samples at 397 cm have a cone of 95% confidence about the mean direction with a half angle of 60°, however this still gives

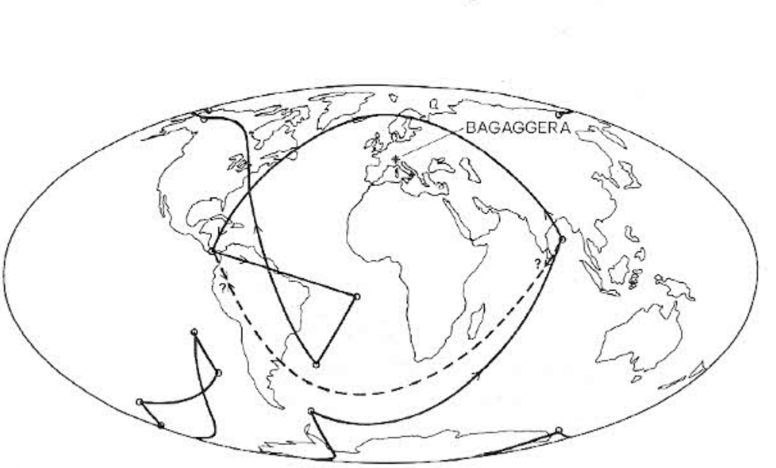

Fig. 12 – Polarity transition at Bagaggera section 8.

a near– sided path, slightly biased towards the west. The diagram uses great circles to join the poles, but the poles for BG85 and BG84 are almost 180° apart so there is little control on this part of the path. The Indian pole may represent an excursion before the reversal, it may be part of the transition with westward drift between 90° E and 90° W, or it may represent the transition, with the Atlantic loop being an excursion.

If it is assumed that the Indian pole represents a pre–transition excursion this path is similar to that of Bruggen. The main part of the transition, the Atlantic reversal is similar to the Lower Jaramillo transition seen at Stirone (Salloway, 1983), and not like the many records for the Matuyama–Brunhes transition. Further work needs to be carried out to test whether the main reversal takes place via the Atlantic or via India, before the transition can be dated definitely.

5. 4. Conclusive remarks.

Paleosols carry a stable remanent magnetization which can be used to date the period of alteration. Most of the paleosols from Bagaggera quarry are normally magnetized, however reversed directions are seen in Units 5 and 8, suggesting that weathering of these deposits took place in the Matuyama.

Beneath these paleosols there is a normally magnetized soil developed on the flysch representing alteration during the Jaramillo Event (0.90 to 0.97 Ma) or before.

The deposits in the southern sub–basin record a transition of the magnetic field which has characteristic similar to both the Lower Jaramillo (0.97 Ma) and Lower Olduvai (1.87 Ma) transitions. No reversed sediments are seen above this, however alteration of some deposits in section 9 may have occurred during a reversed epoch.

6. Discussion. (M. C., G. O.).

The entire stratigraphic sequence of Bagaggera lies on a paleosurface cut into the Bergamo Flysch. The origin of this surface possibly dates back to the Upper Miocene. Similar erosional surfaces, in the surrounding areas have been referred to the Messinian salinity crisis in the Mediterranean Basin (Rizzini & Dondi, 1978; Bini et al., 1978).

The preserved overlying paleosol began to evolve probably already during Pliocene, in a period of direct magnetic polarity. Its pedologic features must be related to an «intertropical» environment that persisted at least for time intervals of the order of 10^4 years. The long period of geomorphic stability testified by this paleosol is interrupted by the regional erosion that can be correlated with that at the base of the Ceppo of Adda formation, therefore probably still of Pliocene age (Orombelli, 1979), and related to a phase of uplift of the alpine margin.

The first phase of aggradation of the piedmont plain which caused the deposition of the Ceppo of Adda, Paderno Member, built up a barrage across the already existing valley and consequently originated the lacustrine basin. The lacustrine facies are therefore transgressive on the eroded paleosol S5.

The deepest lacustrine deposits (9B) are mainly of negative polarity. The transition to the positive polarity, observed near their top (sections 8 and 9), is tentatively referred to the transition of Lower Jaramillo (0.97 Ma). The hiatus between unit 9B and unit 7 may span a time interval between the Jaramillo and the Brunhes.

The angular unconformity between units 9A and 9B probably testifies a phase of tectonic uplift that splits up the lacustrine basin into minor sub–basins, which from now on are characterized by different sedimentary environments and processes.

The lacustrine sediments of Unit 9A, the monogenic breccia (U8), the overlying paleosol and the gravels of Unit 5 show a reversed magnetic polarity and therefore date back to Early Pleistocene.

The lack of organic remains inside the lacustrine sediments of the northern sub–basin (9A) and the monogenic breccia testify a strong slope degradation in a cold environment and an abrupt climatic worsening.

Unit 5 points out a second important aggradation phase, which is correlated, on the basis of the mineralogical and petrographic composition, with the one that caused the deposition of the Ceppo of Adda, Trezzo Member, in the piedmont margin. In this case, unlike the preceding cycle, when the Ceppo reaches only the mouth of the Curone valley, the margin of the aggrading fan penetrates into the valley itself. The transition between Unit 5 and Unit 4 is marked by a lithological, pedological and palaeomagnetic discontinuity and therefore corresponds to an important hiatus in the stratigraphic sequence.

In the southern sub–basin Unit 7 consists of a residual concentration of angular quartz and chert clasts (frost shattered ?), deriving from the reworking of a very developed soil, likely the S5 or S4, developed both on the Flysch bedrock and on the gravel of the margin of the basin. Furthermore the unit contains wood fragments (*Albies alba* Venzo, 1948), clearly related to climatic conditions colder than the present ones. Therefore Unit 7 may have the same paleoenvironmental significance as Units 8 and 9A, but it was deposited a the beginning of the Brunhes, and could be correlated with Unit 4 or with the discontinuity between Units 5 and 4. In the northern sub–basin Unit 5 is followed by another phase of aggradation that causes the deposition of the gravelly loams and of the loams of Units 4 and 3.

A first significant increase of the metamorphic minerals of alpine provenance occurs inside these sediments that, considering their mineralogical and petrographic composition, come from outside the Curone basin. Clay chips deriving from Unit 9A have been observed at the limit between Units 4 and 3: that implies a remarkable tectonic uplift and a subsequent erosion of the first units.

Paleosol S3 develops on top of Unit 3 and testifies a long period of stability in non glacial climatic conditions. Its upper limit is erosional and is overlain by a thin and discontinuous cover of loess slightly affected by pedogenesis (U.3, upper part). A rather short time interval must have passed from its deposition till the following sedimentation of fluvial or fluvioglacial (U2) gravels that southwards go beyond the threshold which divided the two sub–basins. According to their mineralogical and petrographic composition, these gravels belong to the Middle Pleistocene (so called «Ceppo Poligenico», Orombelli & Gnaccolini, 1978). Units 4 and 3 and paleosol S3 are absent in the southern basin, where the lacustrine sedimentation continues with clastic supply from the Curone valley; here clasts of centralpine origin appear only upwards, in the sandy and pebbly fluvioglacial Unit 2, which causes the infilling of the whole basin.

Probably during last interglacial period the S2 paleosol developed on the top of Unit 2. During Late Pleistocene, the Bagaggera basin, was not reached by the outwash sediments of the Lecco piedmont glacier, but only by loess.

The paleosols enclosed in the Bagaggera sequence indicate that important changes occurred in the soil forming processes, at the southern margin of the Alps, during the last few million years. Paleosol with oxic characters, on the Flysch bedrock, developed in humid tropical pedoclimate which acted for a long time (Pliocene – Early Pleistocene) on a surface stable from a morphodynamic point of view. On the contrary, from the upper part of the Early Pleistocene up to the Holocene soil forming processes occurred discontinuously: phases of prevailing weathering alternated with phases of slope degradation and aggradation of sedimentary bodies.

Main pedogenic processes which operated in the paleosols of that period are not so different from that of the Holocene soils of this region and probably required similar pedoclimatic conditions.

7. Conclusions. (M. C., G. O.).

Generally speaking, in the Bagaggera fill the lacustrine facies are progressively replaced by the fluvial and or fluviolacustrine facies. The replacement takes place from the margins towards the center and from bottom to top.

This sedimentary trend is accompanied by a parallel mineralogical and petrographic trend. Sediments of prealpine provenance are gradually replaced by other deposits of centroalpine provenance, but with an appreciable acceleration in the topmost units.

The sedimentary and mineralogical variations are due to important changes in the area upstream the basin and the replacement of fine sediments with coarse ones indicates an increased relief energy, probably due to an uplift of the Alpine margin. Furthermore, as it has already been pointed out for the Paderno stratigraphic sequence, the arrival of centroalpine clasts is caused by an opening towards the Valtellina area through the Lecco branch of Lake Como.

Nevertheless in the Bagaggera sequence, together with the effects of a progressive tectonic evolution there are evidences of alternating glacial and interglacial morphosystems. The former are testified by the slope deposits of U8, by the sediments of U7 and probably by Units 4 and 2 and by the overlying and interbedded loesses; paleosols S4, S3, S2 and S1 certainly indicate a long permanence of the plant cover on stable surfaces in non glacial conditions.

While clear evidences of moraine complexes in the vicinity of Bagaggera are present only from Middle Pleistocene, when the opening towards the Valtellina area takes place, there are geological traces of climatic worsening during Early Pleistocene. The Bagaggera sequence, where not more than five glacial phases have been recognized for the whole Pleistocene, is evidently in contrast with the oceanic records and the palynological sequences, which testify a much greater number of climatic variations. This can be explained by considering that the climatic changes, in particularly unstable conditions like the southern margin of the Alpine chain, interfere with the tectonic activity and that the local glacial geological record (in terms of phases of aggradation and erosion and of expansion and contraction of the glaciers) is the result of a complex geological history where climate fluctuation is but one factor.

APPENDIX I

Profile description.

Profile 1 (described along section 1). (Fig. 7).

Location: 300 m N cascina Barbabella.
Physiographic position: slope.
Parent material: loamy sediments and Flysch bedrock.

Ap + B1 cm 0–30: Yellowish brown (10YR 5/4) silty loam; moist; fine weakly developed subangular blocky; moderately porous, moderately weak; not calcareous; clear boundary.

IIB21t cm 30–55: Reddish brown (5YR 4/4) silty clay loam; moist; strongly developed medium angular blocky; slightly porous, very firm; many small Fe Mn nodules; many discontinuous clay coats on peds; common light gray bordered vertical tongues; not calcareous; clear boundary.

IIB22t cm 55–70: Red (2.5YR 4/6) silty clay, brown (7.5YR 4/4); yellowish brown (10YR 5/8), light brownish–gray (10YR 6/2) mottled; very many medium distinct mottles arranged along the structure; moist; strongly developed platy; few small pores; very firm; many thick red clay coats, mainly horizontal on ped surfaces; not calcareous; sharp wavy boundary.

IIIB21t cm 70–110: Strong brown (7.5YR 5/6) silty loam; moist; strongly developed medium prismatic; few small pores; strong; few small Fe Mn nodules; many reddish brown (5YR 4/4) clay coats on peds; common, light gray (10YR 7/1) brown bordered tongues; not calcareous; clear boundary.

IIIB22 cm 110–130: Red (2.5YR 4/6), brown (7.5YR 4/4), yellowish brown (10YR 5/8) light brownish gray (10YR 5/2) mottled silty clay; very many medium distinct mottles disposed according to the structure; moist; strong developed medium platy; few small pores; very firm; many thick red clay coats on ped surfaces; not calcareous; sharp wavy boundary.

IVB21t cm 130–210: Yellowish red (5YR 5/6) silty clay loam; red (2.5YR 4/6) common fine mottles; rare to common small weathered stones; moist; coarse prismatic strongly developed; common small pores; strong; many clay coats continuous on peds; common light gray brown bordered vertical tongues; at the top of the horizon they are up to 5 cm wide and some laminae of the upper horizon sink in them; in the lower part of the horizon the tongues become thinner and branch out; not calcareous; gradual boundary.

IVB22t cm 210–300: Red (2.5YR 4/6) clay loam; few medium gray mottles, large abundant on stone surfaces; angular flysch breccia stones, not in contact; stones have a thin yellow cortex; they are dark red (2.5YR 3/6) and have few small yellowish red mottles; moist; weakly developed coarse angular blocky strong; few entire clay coats on ped surfaces; not calcareous; clear boundary.

VB3 cm 300–600: Reddish brown (2.5YR 5/4) weathered Cretaceous flysch; sandy silty and marly layers.

VC cm 600–1850: Light olive brown (2.5YR 5/4) weathered sandy Cretaceous flysch; rare, dark red clay coats along bedding surfaces; not calcareous; clear boundary to core stones on unweathered and calcareous flysch, in the lower part of the horizon.

Profile 2 (described along section 9). (Fig. 8).

Location: close to a pipeline box, along the road from Bagaggera to Fornace Barbabella.
Physiographic position: on a flat terrace, not far from the terrace scarp.
Parent material: loess and fluviatile sands.

Ap cm 0–6: Dark brown (10YR 4/3, 3/3) silty clay loam; few small fragments of bricks; moist; subangular blocky fine weakly developed; few fine pores, moderately firm; not calcareous; clear wavy boundary.

B1 cm 6–40: Dark brown to brown (10YR 4/3), silty clay loam; moist; fine subangular blocky weakly developed, moderately weak; few pores; common small Fe Mn nodules; not calcareous, gradual irregular boundary; Upper Palaeolithic artefacts and few charcoals are buried at this level.

IIB21tx cm 40–115: Dark yellowish brown (10YR 4/6) silty clay loam; few fine faint mottles; moist; medium angular blocky strongly developed; moderately porous; strong; common Fe Mn nodules; few discontinuous clay and Fe Mn coats on peds and inside pores; common light gray (10YR 7/1) yellow fringed, vertical tongues crossing the horizon; common small Fe Mn nodules; not calcareous; gradual boundary.

IIB22t cm 115–120: Yellowish brown (10YR 5/6) silty clay; moist; medium platy strongly developed; slightly porous; strong; common entire horizontal pale brown (10YR 7/2) clay coats some millimeters thick; not calcareous; abrupt boundary.

IIIB21t cm 120–181: brown, dark brown (7.5YR 4/1) silty clay loam; moist; medium prismatic strongly developed; moderatly porous; strong; common thick clay coats dark reddish brown (5YR 2/4) and common Fe Mn coats on peds and inside pores; common light gray tongues; in the lower part they become thinner and branch out; not calcareous; gradual boundary.

IIIB22t cm 181–240: Yellowish brown (10YR 5/8) clay; moist; common medium faint dark yellowish brown (10YR 4/6) mottles; few small cherty stones; moist; coarse angular blocky medium developed; slightly porous; firm; common dark reddish brown dark red (5YR 3/4, 2.5YR 3/4) clay coats thick and entire on peds; not calcareous gradual irregular boundary.

IIIC1 cm 240–400: Yellowish brown (10YR 5/6) silty clay loam and sandy clay loam; moist; coarse blocky very weakly developed; firm; many distinct medium sized mottles with wide light gray reticular pattern (10YR 7/2); few discontinuous reddish brown clay coats only in the upper part of the horizon; common small Fe Mn soft concentrations.

Unit 6/2 (IIIC2, IIIC3) and the units of the fluviolacustrine sequence are present below. The carbonates occur again only in unit 9 at a depth of about 15 meters below the present ground surface.

Profile 3 (described along section 6 and 4). (Fig. 8).

Location: 100 m N from Cascina Barbarella.
Physiographic position: on the quarry wall cut into the same terrace of the pipeline profile.
Parent material: loess and fluviatile sediments.

The upper part of the profile is completely similar to the profile 2 down to a depth of 250 centimeters, the description starts again from a pebbly horizon corresponding to the preceeding IIIB22t.

IVB23t cm 250–295: Dark brown (7.5YR 4/4) sandy loam; abundant medium and small rounded–sub rounded weakly weathered stones; moist; medium and coarse blocky weakly developed; moderately porous firm; common horizontal grey mottles; common brown clay coats; not calcareous; abrupt boundary.

VB21 cm 295–318: Strong brown (7.5YR 5/8) silty clay loam; moist; prismatic medium strongly developed slightly porous; very firm; common small soft Fe Mn concentration; many black Fe Mn coats continuous on the surface of the peds; inside the peds they show dendroid pattern; not calcareous; clear wavy boundary.

VIB21t cm 318–458: Yellowish red (5YR 4/6) silty clay loam; dark brown (7.5YR 4/4) common faint medium mottles; few very small quartz angular stones; moist medium–coarse prismatic strongly developed, strong; common small Fe Mn nodules at the horizon boundary; many black Fe Mn coats, continuous on peds; thick brown (7.5YR 5/2) clay coats; continuous common on peds and inside pores. At the lower boundary of the horizon, pinkish gray (7.5YR 7/2) streaks showing a wide reticular pattern; not calcareous; linear clear boundary.

VIB22 cm 458–577: Yellowish red (5YR 5/8) silty clay loam; many medium distinct mottles (10YR 7/3); very pale brown; few medium weathered stones; moist; platy weakly developed; very slightly porous; firm; many black Fe Mn coats discontinuous on peds; many thick clay coats on peds, not calcareous; clear linear boundary.

VIIB21t cm 577–702: Strong brown (7.5YR 5/6) silty loam; few stones to many stones (in the southern part of the outcrop) mainly of chert and quartz, and reddish weathered sandstone; moist; coarse–medium angular blocky strongly developed; firm; moderately porous; common Fe Mn nodules in the lower part of the horizon; many red coloured clay coats on peds and inside pores (5YR 4/3); common small vertical glossae (10YR 7/6); not calcareous clear linear boundary.

VIIB22cn cm 702–727: dark brown (7.5YR 4/2) silty loam; few small stones; moist; medium angular blocky weakly developed; moderately firm; many Fe Mn black nodules; porous; common clay coat on peds; not calcareous; clear linear boundary.

VIIIB2 cm 727–800: brown (7.5YR 5/4) clay; common small yellowish–brown mottles (10YR 6/4); lenses of weathered pebbles; fine angular blocky weakly developed; moist; moderately firm; moderately porous; common Fe Mn black coats and red clay coats (5YR 5/4) on pores, on peds and on pebbles surfaces; not calcareous; not exposed boundary.

The lacustrine deposits of unit 6 (Fig. 3) are present underneath and overlie the Flysch of the bedrock and the contact is erosional. The bedrock shows on the threshold the following characteristics:

Bg cm 0–170: Olive (2.5YR 6/4) brown (10YR 8/1) and red (5YR 4/2); mottled coarse quartz sand; massive; firm; bedding is still well preserved; common pores; diffuse boundary.

Bx cm 170–350: Pale brown (10YR 5/8) coarse quartz sand; massive; few pores; firm to very firm; discontinuously cemented by silica; not exposed boundary.

APPENDIX II

Short micromorphological description. *

Profile 1

Horizons	IIB21	IIIB21	IIIB22	IVB21	IVB22t	VB3
Skeleton grains	poorly sorted quartzic sand	—do—	—do—	—do—	—do—	well sorted quartzic coarse sand
Lithorelicts	—	angular quartz (C)	—do—	—	angular quartz and chert	—
Pedorelicts	rounded fragments from IIIB21 & IVB22 (M)	—	—	—	rounded fragment from VB3 (M)	—
Voids	metavughs (C)	planes (C) channels (F) metavughs (F)	—do— planar distribution	—do—	branching channels (C) wide metavughs (C)	metavughs (C)
Basic fabric	porphiroschelic	—do—	—do—	—do—	—do—	agglomero-plasmic
Plasma	clear brown	1 brown 2 pale yellow	—do—	—do—	—do—	red—brown
Plasmic fabric	silasepic (insepic)	1 argillasepic 2 vomasepic bimasepic	1 insepic 2 masepic	—do—	—do—	undulic
Cutans A	A1 (C) A complex (CC)	A1 (M) A2 (F) A complex (C)	A1 (C) A complex (M)	A1 (C) A complex (C)	—do—	thin A1 (FF)
Cutans B	—	—	—	—	—	neosesquans (C)
Glabulae	papules (M) Fe Mn nodules (F)	papules (M)	—	papules (C)	—do—	—
Other features	zones of washed silt	—	—	zones of washed silt	—	—

---

* Micromorphological description according Brewer (1976).
Cutans: A1 Ferriargillans, laminated strongly birefrangent;
A2 yellow argillans, strongly birefrangent;
A complex cutans: ferriargillans interbedded with siltans, matrans and skeletans.
(F) few; (C) common; (M) many.

Profile 2				Profile 3			
Horizons	B1	IIB21tx	IIIB21t	IVB23t	VIB21	VIIB21t	VIIIB2
Skeleton grains	moderately sorted quartzic silt and muscovite	—do—	poorly sorted quartzic sand	—do—	—do and quartzic silt and muscovite	—do—	—do—
Lithorelicts	—	—	angular quartz (C)	angular chert sandstones Met. (M)	—	angular quartz and chert (F)	angular quartz and chert (M)
Pedorelicts	—	—	—	—	—	rounded fragment VIIIB2 (F)	—
Voids	metavughs (C)	channels (FF) metavughs (C)	vughs (M) planes (C) channels (C)	metavughs (C)	—do—	channels (F) vughs (C)	planes (C) channels (C) vughs (C)
Basic fabric	agglomero-plasmic	porphiro-schelic	—do—	—do	—do—	—do—	—do—
Plasma	clear brown	1 brown 2 pale yellow	—do— a little redder	1 strong brown 2 pale yellow	—do—	strong brown	—do—
Plasmic fabric	silasepic	1 insepic 2 schelamsepic	bimasepic	vomasepic	insepic	masepic (unistrial)	masepic
Cutans A	—	A1 (C) A complex (M)	A complex (M) sesquans (F)	A1 (M) A2 (M)	A1 (C) sesquans (C)	A1 (C) A complex (C) sesquans (C)	A1 (M) A complex (M)
Cutans B	—	neosesquans (C)	neosesquans (C)	—	—	—	—
Glabulae	nodules Fe Mn (F)	papules (C) nodules Fe Mn (F)	—	—	Fe Mn nodules (C)	Fe Mn nodules (C)	papule (C)
Other features	—	—	—	—	—	—	—

---

* Micromorphological description according Brewer (1976).
Cutans: A1 Ferriargillans, laminated strongly birefrangent;
A2 yellow argillans, strongly birefrangent;
A complex cutans: ferriargillans interbedded with siltans, matrans and skeletans.
(F) few; (C) common; (M) many.

REFERENCES

Billard A. (1974) - Paléosols quaternaires de l'alta pianura de Milan, interprétation stratigraphique et paléoclimatique. *Bull. Ass. Franç. Etude Quat.*, 1973–74, n. 37, pp. 267–286, 2 fig., Paris.

Billard A. (1977) - Quaternary stratigraphy of stepped glaciofluviatile terraces in the Italian piedmont of the Alps; a criticism and a proposal for new criteria of classification. *IGCP Project* 73/1/24, Rep. n. 4, pp. 53–66, 2 fig., Prague.

Billard A. (1980) - Sols lessivés dégradés à glosses et à fragipan; genèse et régionalisation. Notes et comptes rendu du groupe de travail «Régionalisation du périglaciaire», n. 5, pp. 23–43, 4 fig., Paris.

Billard A., Bucha V., Horacek J. & Orombelli G. (1982) - Preliminary paleomagnetic investigations on Pleistocene sequences in Lombardy, Northern Italy. *Riv. It. Paleont. Strat.*, v. 88, n. 2, pp. 295–318, 11 fig., Milano.

Billard A. & Fedoroff N. (1977) - Interglacial – periglacial pedogenetic cycle in Northern Italy and France. *X INQUA Congress*, Abstracts 10, p. 35, 1 fig., Birmingham.

Bini C., Busoni E. & Ferrari G. A. (1977) - Figure pedologiche nei paleosuoli: orizzonti a pseudogley in un suolo della Val di Chiana. *Boll. Soc. Geol. It.*, v. 96, pp. 169–186, 3 fig., 4 tab., Roma.

Bini A., Cita M.B. & Gaetani M. (1978) - Southern Alpine Lakes. Hypotesis of an erosional origin related to the Messinian entrenchement. *Marine Geol.*, v. 27, pp. 271–288, 8 fig., Amsterdam.

Bouma J., Pons L. J. & Schuylenborgh van J. (1968) - On soil genesis in temperate humid climate. VI. The formation of glossudalf in loess (silt loam). *Neth. J. Agric. Sci.*, v. 16, pp. 58–70, 4 fig., Amsterdam.

Brewer R. (1976) - Fabric and mineral analysis of Soils. V. of 482 pp., 133 fig., Huntington.

Bucha V. & Sibrava V. (1977) - On the correlation of Quaternary stratigraphy stages in the northern emisphere. *IGCP Project 73/1/24*, Quaternary Glaciations in the Northern Hemisphere, Rep. n. 4, pp. 91–101, 3 fig., Prague.

Chardon M. (1975) - Les Préalpes Lombardes et leur bordures, 2 v., 655 pp., 10 pl., 140 fig., 3 maps, Librairie H. Champion, Paris.

Cipriani N., Magaldi D. & Malesani P. (1976) - Studio mineralogico–petrografico delle Arenarie di Sarnico (Prealpi Bergamasche) e correlazione con la Pietraforte (Toscana). *L'Ateneo Parmense*, v. 12, n. 3, pp. 285–309, 4 fig., Parma.

Cox A. (1975) - The frequency of geomagnetic reversals and the symmetry of the non–dypole field. *Rev. Geophys. Space Phys.*, n. 13, pp. 35–51, New York.

Dijkerman J. C., Cline M. G. & Wolson G. W. (1967) - Proprieties and genesis of textural subsoil lamellae. *Soil Science*, v. 104, n. 1, pp. 7–16, 3 fig., Washington.

Duchaufour Ph. (1977) - Pédologie, 1 Pédogenèse et classification. V. of 477 pp., 16 pl., 90 fig., Paris.

Fitzpatrick E. A. (1956) - An indurated soil horizon formed by permafrost. *Journ. Soil Science*, v. 7, pp. 248–254, Washington.

Fitzpatrick E. A. (1980) - Soils. V. of 352 pp., 4 pl., 73 fig., London.

Gabert P. (1962) - Les plaines occidentales du Pô et leur piedmonts (Piémont, Lombardie occidentale et centrale): étude morphologique. 531 pp., 223 fig., 5 maps, Louis Jean, Gap.

Hillhouse J. & Cox A. (1976) - The Brunhes–Matuyama Polarity Transition. *Earth Planet. Sci. Lett.*, v. 29, pp. 51–64, Amsterdam.

Hoffman K. A. (1979) - Behaviour of the Geodynamo during reversal: a Phenomenological Model. *Earth Planet. Sci. Lett.*, v. 44, pp. 7–17, Amsterdam.

Hoffman K. A. & Fuller M. (1978) - Transitional field configurations and geomagnetic reversal. *Nature*, n. 273, p. 715, London.

Jamagne M. (1973) - Sols et paléosols sur loess dans le Nord de la France, 9^e Congr. Internat. INQUA: Le Quaternaire, Géodinamique, stratigraphie et environnement. *Suppl. Bull. Assoc. Franç. Etude Quaternaire*, pp. 360–372, 7 fig., Paris.

Koci A. & Sibrava V. (1976) - The Brunhes–Matuyama boundary at Central European localities. *IGCP Project* 73/1/24, Quaternary glaciations in the Northern Hemisphere, Rep. n. 3, pp. 135–137, 6 fig., Prague.

Mankinen E. & Dalrymple G. B. (1979) - Revised geomagnetic polarity time scale for the interval 0–5 m.y. B.P. *J. Geophys. Res.*, v. 84, pp. 615–626, Oxford.

McElhinny M. W. (1973) - Palaeomagnetism and plate tectonics. V. of 342 pp., 30 pl., 14 fig., 6 maps, Cambridge.

Orombelli G. & Gnaccolini M. (1978) - Composizione petrografica e provenienza del «ceppo» di Paderno d'Adda. Gruppo di Studio del Quaternario Padano, Quaderno 4, pp. 7–30, 8 fig., Parma.

Orombelli G. (1979) - Il Ceppo dell'Adda: revisione stratigrafica. *Riv. It. Paleont. Strat.*, v. 85, n. 2, pp. 573–652, 24 fig., Milano.

Rizzini A. & Dondi L. (1978) - Erosional surface of Messinian age in the subsurface of the Lombardian plain (Italy). *Marine Geol.*, v. 27, pp. 303–325, 15 fig., Amsterdam.

Salloway J. C. (1983) - The structure of the geomagnetic field during polarity transitions and excursions. *Doct. Ph. Th. Univ. Edin.*, v. of 377 pp., 183 fig., Edinburgh.

Smalley I. J. & Davin J. E. (1982) - Fragipan horizons in soils; a bibliographic study and review of some of the hard layers in loess and other materials. New Zealand bibliographic report 30, Depart. Scient. Industr. Res., 122 pp., 32 fig., Wellington.

Soil Survey Staff (1975) - Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Agricultural Handbook n° 436. *Soil Conservation Serv. U.S.D.A.*, v. of 499 pp., 12 pl., 38 fig., Washington.

Stoops G. (1982) - Micromorphology of the oxic horizon. *Soil Micromorphol.*, v. 2, pp. 419–439, 2 fig., Cambridge.

Stober J. & Thompson R. (1979) - An investigation into the source of Magnetic minerals in some Finnish Lake Sediments. *Earth Plan. Sci. Lett.*, v. 49, pp. 464–474, Amsterdam.

Van Schuylenborgh J. (1973) - Sesquioxides formation and transformation. *Pseudogley & Gley*, pp. 93–102, 5 fig., Weinheim.

Van Vliet B. & Langoror R. (1981) - Correlation between fragipans and permafrost with special reference to silty Weichselian deposits in Belgium and Northern France. *Catena*, v. 8, pp. 137–155, 4 fig., Destedt.

Venzo S. (1948) - Rilevamento geomorfologico dell'apparato morenico dell'Adda di Lecco. *Atti Soc. It. Sc. Nat.*, v. 87, pp. 79–140, 2 pl., 4 fig., 1 map, Milano.

Venzo S. (1952) - Geomorphologische Aufnahme des Pleistozäns (Villafranchian – Würm) im Bergamasker Gebiet und in der östlichen Brianza: Stratigraphie, Palaeontologie und Klima. *Geol. Rundschau*, v. 40, pp. 109–125, 10 fig., Stuttgart.

Venzo S. (1955) - Le attuali conoscenze sul Pleistocene lombardo con particolare riguardo al Bergamasco. *Atti Soc. It. Sc. Nat.*, v. 94, pp. 155–200, 4 pl., 8 fig., Milano.