AIRPHOTO INTERPRETATION OF GRANULAR CONSTRUCTION MATERIALS FOR ENGINEERING PURPOSES IN TREMP BASIN, SPAIN

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ABSTRACT. —This paper deals with the application of airphoto interpretation techniques to a survey of granular construction materials carried out in Tremp Basin, Northern Spain.

A preliminary construction materials map was prepared by photo interpretation using conspicuous landforms, drainage patterns, erosional features and gray tones as photo indicators. The map proved to be highly accurate when field checking was carried out and only very limited field work was found to be necessary to obtain fully reliable results. If a construction material survey had been carried out by conventional field methods such detailed results could have not been obtained in the short time available. This demonstrates the importance of aerial photographs in construction materials survey.

INTRODUCTION

The area under investigation is located within the province of Lerida (Northern Spain), about hundred kilometers north of the provincial capital (Fig. I).

The Tremp Basin, which occupies the main part of the study area, is surrounded by mountains and is at an elevation of about 550 m above sea level. It has a surface area of about 215 km^2.

The granular materials of the area are mainly mixtures of gravel, sand, silt and silty clay. These granular materials usually originated from fluvial denudational processes. The engineering quality of the materials range from well-graded deep, clean gravels to clayey plastic soils. They show marked variations both areally and vertically. They cover an area of approximately 185 km^2 and their thickness varies between two and five meters.

AIRPHOTO INTERPRETATION METHODS

Airphoto interpretation of granular materials is basically concerned with making inferences and deductions from information appearing on photographic imagery.

Twenty-four aerial photographs were used at a scale of 1:33,000 to carry out the preliminary survey. Stereoscopic examination of the photographs in the laboratory led to the compilation of preliminary maps that were subsequently used in the field. The field work was concentrated on an area covered by twelve photographs. The other photographs were used only for establishing the general morphogenetic relationships of specific landforms with their surrounding areas. The landforms appearing in the stereoscopic image greatly assist, since a morphogenetic interpretation enables deductions to be made concerning the materials with which they are associated.

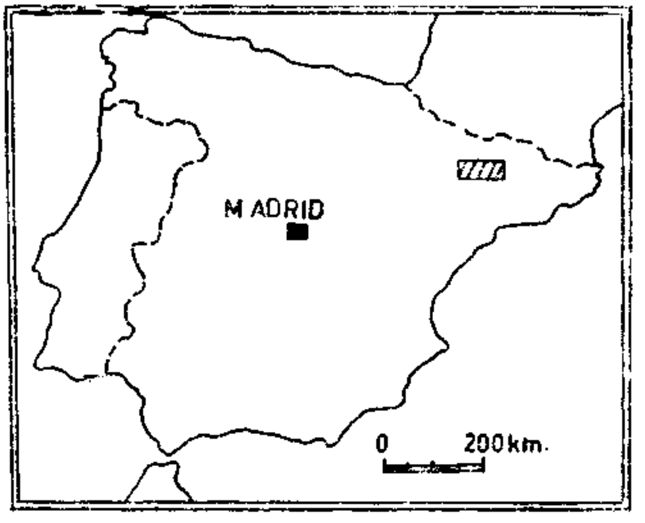

Fig. 1 - Location map of the study area.

The use of photo indicators as a basis for aerial photographic identification of granular materials is elaborated in this study. The interpretation is implemented through the use of the stereoscopic model and photographic gray tones, these being used to identify landforms, erosion types, vegetation cover and drainage conditions. Recognition of these features often permits the identification of their constituent deposits. They therefore act as valuable photo indicators during the process of photo interpretation. A short explanation of these photo indicators is given below.

a. The use of landforms to identify construction materials

The landforms can be identified easily by stereoscopic inspection of the aerial photographs. They are especially useful for finding small occurrences of granular deposits that are difficult to locate in the field, due to lack of exposure. Their significance is that they allow inferences to be made regarding the granular materials of the morphology. In the study area a high correlation was found to exist between landform and material type.

In order to indicate the relationships between the photographic characteristics of the landforms and granular materials, the table shown on page 77 was prepared (Table I). It will be seen that each landform is indicative of a special type of material illustrating the fact that the type of material can be deduced from interpretation of their morphogeneses.

b. Drainage and erosional features

A dense and finely textured drainage pattern with rounded ridges and gullies may indicate impermeable, highly plastic or clayey materials. High runoff and a low infiltration into the impermeable material account for these forms. However, in place of low relief and high water table, the above-mentioned indicators may not be significant. This pattern contrasts with areas where there is a lack of surface drainage due to the low runoff and high infiltration, indicating the existence of permeable and well-drained gravel, sand or silty sand materials (Hittle, 1949). In such areas the cross-sections of gullies are U-shaped, whereas in slightly clayey materials they are steep and V-shaped.

Table - 1
Photo characteristics of landforms and associated granular materials occurring in the area

Photo characteristics	*Landforms*	*Type of material*	*Origin of material*	*Grading*
Extensive flat surface with abrupt edges, usually cultivated, shows lighter phototone when higher and/or well-drained	River terraces	Gravel and sand	Fluvial	Usually well-graded
Braided river channel, natural levees, point bars, islands and flood discharge channels, occasionally with water. Vegetation at the edge of T_1. Variable phototones	Flood plain	Usually coarse material, boulders, gravel and occasional sand pockets	Fluvial	Well-graded
Gently sloping slightly convex fan shape, lighter phototone, vegetation increases towards the boundary of the unit	Alluvial fan	Gravel, boulders and some sand	Fluvial	Moderately graded
Flat to gently sloping smooth surfaces, sometimes isolated inclined table form, distinctive boundary, sparse vegetation occasionally cultivated. Mostly lighter phototones	Glacis *	Angular or sub-angular gravel, sand and silt.	Denudational	Poorly graded
Steeply sloping apron shape, light phototone, no vegetation	Scree	Angular gravel with silt	Denudational	Poorly graded
Moderately steeply sloping irregular slope. Cultivated and occasional trees. Mottled phototones dark to medium light	Colluvial slope	Some angular gravel and blocks with abundant silt and clay	Denudational	No grading, deep, plastic soil

* Defined here as a landform produced by the transportation and accumulation of disintegrated materials over short distances. It is usually associated with sheet flood, producing a slope of approximately 7 degrees.

c. The interpretation of gray tones

Variations in gray tone levels on the aerial photographs are an important factor in identifying surficial deposits. For example, a dark-colored material may appear with a dark phototone and a light-colored material with light tone (Mollard, 1962). This is of course providing the vegetation does not interfere. On the other hand, whatever the natural color of the material, fine-grained deposits, provided that they are not moist, usually appear as lighter tones, due to the high reflection of light from all the grains (Miles, 1962). Conversely, fine-grained materials are less permeable and thus have high water-holding capacity. They, therefore, generally have a darker tone, since the water absorbs and transmits the light energy. So, a dark phototone usually shows a poorly drained material, which in most cases indicates clay or silty clay or very fine organic matter. On the contrary, light phototones usually show a poorly drained material, which in most cases indicates clay or silty clay or very fine organic matter. On the contrary, light phototones usually indicate well-drained materials such as gravel, sand and coarse-grained silt (see the stereograms).

However, it should be emphasized that the photographic gray tones may also give a false impression due to certain photographic factors (e.g. sensitivity range of the film and the processing). The tones always have to be compared with the over-all gray tone pattern of adjacent photographs.

d. Vegetation

Vegetation often reflects the nature of the soil and its moisture content. For instance, a dense and flourishing vegetation may indicate fertile soil with a high moisture content; consequently it could be concluded that it is a fine-grained clayey soil.

However, photo-indicators of vegetation will also depend on climatic conditions. They arc generally more indicative in arid and semiarid areas than in humid tropical and temperate areas where the ground is largely obscured by dense vegetation.

PALEOMORPHOLOGICAL DEVELOPMENT OF THE AREA AND MATERIALS

The aerial photographs have also been extremely useful in establishing the paleomorphological history of the area. This is because they allow the interpreter to have a general view of several landforms simultaneously and consequently to make comparisons and establish a morphogenetic relationship between them. The compilation of a geomorphological map led to the acquisition of a complete picture of the structure and morphology of the area. This made it possible to interpret the paleomorphological evolution of the materials.

Generally, there is an east-west trend of all geological formations resulting from the north-south directed forces of the Pyrenean orogenesis. The effect of these forces decreases from the older to the younger members of the existing rock formations. A north-south cross section across the Pyrenees reveals the numerous anticlines and synclines that exist. The surveyed area covers one of these synclines and part of an associated anticline. Throughout part of the area, due to the effect of erosional processes, monoclinal ridges and hogbacks have been produced with subsequent and consequent valleys formed in the alternating weak and hard beds. Elsewhere the wide syncline is strongly eroded by the rivers. As a result, a large area inversion of the relief has taken place. The eroded basin (The Tremp Basin) has a rectangular shape and extends in an east-west direction. Paleocene red marls predominate within it and are usually covered by Quaternary drift materials, occasionally exposed on the slopes and where residual hills exist.

Downstream to the south Pallaresa River enters a gorge which is formed in resistant rocks occurring in hard limestone. In the early Pleistocene, the channel and the gorge of the Pallaresa River was approximately 150 m higher than at present. This may be associated with the accumulation and planation due to the low angle of the equilibrium profile. The materials removed from the slopes were transported in a silty matrix along the gentle slopes and gradually accumulated.

As a result of these processes, two important accumulation and planation phases have developed, giving rise to two different river terrace and glacis levels. The first phase produced the high glacis which coincides with the high terraces (T_4). It is largely an erosional glacis with deposits between 600 m and 700 m above sea level. This glacis deposits probably accumulated under cold wet climatic conditions in the earlier part of the Pleistocene period. It should be remembered that, generally speaking, glacis formation can be generated by sheet floods and decreased percolation resulting from periglacial conditions (Photo 3). This high erosional glacis occurring at the foot of the slopes has a relief range of 50 m and a low gradient to T_4. These two features, therefore, were formed in the same or almost the same period.

During this first phase, some tributary rivers were flowing to the main river (The Pallaresa). Some of the T_4 remnants thus are formed by those tributary rivers but not the Pallaresa itself. These remnants are located to the west of the Pallaresa River and have a northwest-southeast direction and a linear shape (Photo I). The flow direction of the river thus is indicated. The grading and attitude of the fragments, in particular their positions and upstream inclinations with long axes approximately perpendicular to the channels, also indicate suchaflow direction. In the transverse cuts of these terraces, fossil channels have been identified with fossil terrace edges. An interesting observation is that the primary channel of one of these rivers is very small and only 5 m wide, but broadens step by step up to 25 m or even more in the upper layers. This suggests that the downcutting of the river gradually increased following an accumulation stage corresponding to that first accumulation and planation period.

To the east of the Pallaresa River, some terrace materials also were identified on top of several aligned residual hills which are flat topped due to presence of gravel deposits. They are probably preserved due to the permeable materials of the gravel cap which does not erode away and thus protects the underlying formation. These materials and aligned hills may either correspond to the former channel of the River Pallaresa or to that of another river joining the Pallaresa from the east.

After this planation and accumulation period, linear river work suddenly started and an erosional period began again in the area. This strong erosion phase was caused by a change in the hydrological regimen of the Pallaresa River which in all likelihood was initiated by a climatic change. This is a time of deepening of the Pallaresa gorge and the dissection of the erosional glacis and the T_4 level. The Pallaresa River and its tributaries thus were considerably lowered. This erosional period finally was stabilized at a lower level, where the T_3 and the low glacis accumulated. This is the second main planation and accumulation period.

The materials of this period are thicker and extend long distances. At this stage, both glacis and terraces are distinctively flatter than the previous ones, which is an indication of a lower angle equilibrium in the basin (Photo3).

Renewed linear erosion subsequently caused further incision of the gorge and a downcutting of the river channels of approximately 20 m. Due to this cutting the T_3 terrace emerged and the Pallaresa incised to the T_2 terrace level (Photo I). This is also the time of the formation of alluvial fans which frequently occur along the Pallaresa River covering the T_2 terraces. The fact that these fans contain boulders, blocks and gravels with little silt content points to their rapid formation, corresponding to the rapid incision period of the T_3 terraces.

At present, the river work is confined to the existing channel and the edge of the T_2 terraces is not more than two meters high in some localities, whereas in other areas the T_2 terrace gently emerges with the meandering course of the Pallaresa River. Here the river is in direct contact with the T_3 terrace edge giving rise to a high and steep scarp.

T_1 is not easily distinguishable from the flood plain (Photo I).

IDENTIFICATION, CLASSIFICATION AND THE MAPPING OF THE MATERIALS

Using aerial photographs, a preliminary construction materials map of the area was made on the grounds of recognizable morphogenetic boundaries. These units formed a preliminary sampling scheme for the area.

It was found, however, during the course of the field work that such units could be further divided on the basis of the physical characteristics of the materials. From these sub-units representative samples were collected for laboratory analysis.

The analysis of grain size distribution, plasticity and moisture content have been carried out (Lambe, 1951) on each sample to supplement the photo interpretation and field observations. The results of the analyses are given in Table 2.

The final identification of the boundaries of units of granular materials was not easy, due to transition in vertical and lateral senses. Therefore minor details in the boundaries were generalized for the sake of the clarity of the map (Fig. 2). However, the final boundaries of the proposed units, plotted after the field sampling and laboratory analysis, appear to be precise enough to facilitate the location and extraction of the materials.

In the denomination of the units, the unified soil classification system of Casagrande (l947) is followed. Eleven different units are identified in the area, as shown in the legend of the construction materials map (Fig. 2).

Table - 2

Engineering properties of materials

Laboratory data on representative samples						
Symbol	*Plasticity (1)*	*Moisture (2) content (%)*	*Particle size % (3)*			
			Gravel	*Sand*	*Silt and clay*	*No. of samples*
AGS	40	44	62	37.6	0.4	two samples
AGS	none	24	86	13.8	0.2	
GW	none	—	79	21	0.05	two samples
GW	none	—	80	19.9	0.05	
GP	none	—	81	18	0.1	two samples
GP	none	—	80	19.5	0.5	
ML	28	43	4	10	86	one sample
AGP	none	19	67	33	—	two samples
AGP	none	19	81	18.8	0.2	
SC	21	36	—	—	100	one
GS	none	12	76	23	0.1	one
SP	none	11	74	25.8	0.2	one
GM	none	39	67	32.7	0.3	two samples
GM	none	11	36	63.2	0.8	

(1) Atterberg; (2) Gravimetry; (3) Sieving and hydrometry.

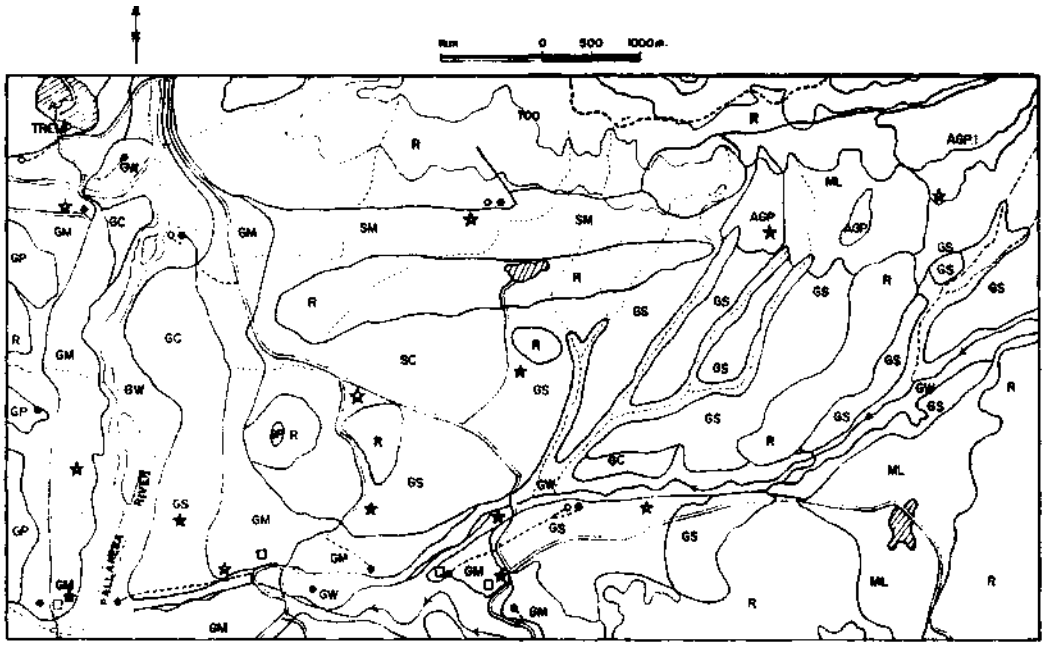

Fig. 2 - Construction materials map.

	MATERIALS	LANDFORMS	SUITABILITY/USES OF MATERIALS
GW	Gravel, sand mixture	Flood plain	Suitable for concrete
GP	Gravel	High terrace	Suitable for concrete, washing is necessary
GM	Silty gravels	Accumulation Terrace T_3	Suitable after washing & screening
GC	Clay, gravel, sand mixture	Accumulation Terrace T_2	Suitable after washing & screening
GS / SC / SM	Angular gravel, silt mixture	Low glacis	Suitable after washing & screening
AGP	Angular gravel, silt mixture	High glacis	Suitable after washing & screening
SP	Sand, gravel, silt mixture	Alluvial fan	Suitable
ML	Silt, clay, angular gravel	Colluvial slope	Not suitable
R	Consolidated (rock) materials		

QUARRIES :

□ Exist • Recommended ○ Potential Hauling road

★ Penetrometre and soil sampling sites

THE EXPLOITATION ECONOMICS OF THE MATERIALS

The value of any engineering material is a function of its properties and volume. But the economics of its exploration also depend upon transport factors, such as distance to the proposed project and the condition of the hauling roads.

The distance to the main roads of the potential, recommended and existing quarries indicated on the construction materials map (Fig. 2) is such that all of them are reasonably accessible. The hauling roads from the quarries to the main roads are indicated with black thick dashed lines. These lines are drawn taking topographic obstacles, drainage lines and flood dangers into consideration. The possibilities for easy accessibility and long-term excavation also have been studied.

At some localities, quarries were recommended taking into account the ease of transportation to the main road from above, for instance, by shovelling down the material using gutters, etc.

The roads to the existing quarries are usually in good condition. Only some minor stabilization and levelling will be needed for their efficient operation throughout the year. The recommended and potential quarry roads have to be constructed. As their distance from the main roads is not very great, the construction will be neither difficult nor expensive.

CONCLUSION

This paper has demonstrated the importance of using air photographs when conducting surveys of granular construction materials. In many cases it has been proved possible in this investigation to relate specific landforms, observed on the photographs to different types of granular materials. The predictive ability of this technique led to considerable time saving, when compared with a conventional ground survey. It is estimated that field work was reduced by sixty percent. This was helped by the fact that in the area under consideration the types of landforms were easily identifiable on the aerial photographs.

Aerial photographs allow a general view of all the landforms of the area to be seen simultaneously and consequently they can be related to one another from the point of view of their origin.

The use of air photographs is, of, course, dependent on the ability and experience of the photo interpreter. Nevertheless, in all studies such as the present one, it seems that the preliminary analysis of air photographs is extremely helpful in devising a sampling program for field observations.

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Photo 1 - The stereogram shows the terrace levels and alluvial fans of the best source of granular materials along the Pallaresa River in the area. The light-gray phototone of higher units (T_4 & T_3) indicates the existence of well-drained, coarse-grained materials. The dark-gray phototones occupying the lower units indicate the fine-grained materials with a high water content. The relationship of all the levels as mentioned in the text can also be seen in the stereogram.

Photo 2 - The stereogram shows the scree fans (S), high (H) (AGP1 on the map) and low glacis (L) formations. The preserved smooth surface and shallow drainage lines on the high glacis level indicate the high percolation of the surface water and thus allow the deduction of the existence of coarse-grained materials. The medium-gray phototone of the unit is due to the vegetation cover. Light phototoned low glacis also indicates the coarse-grained materials.

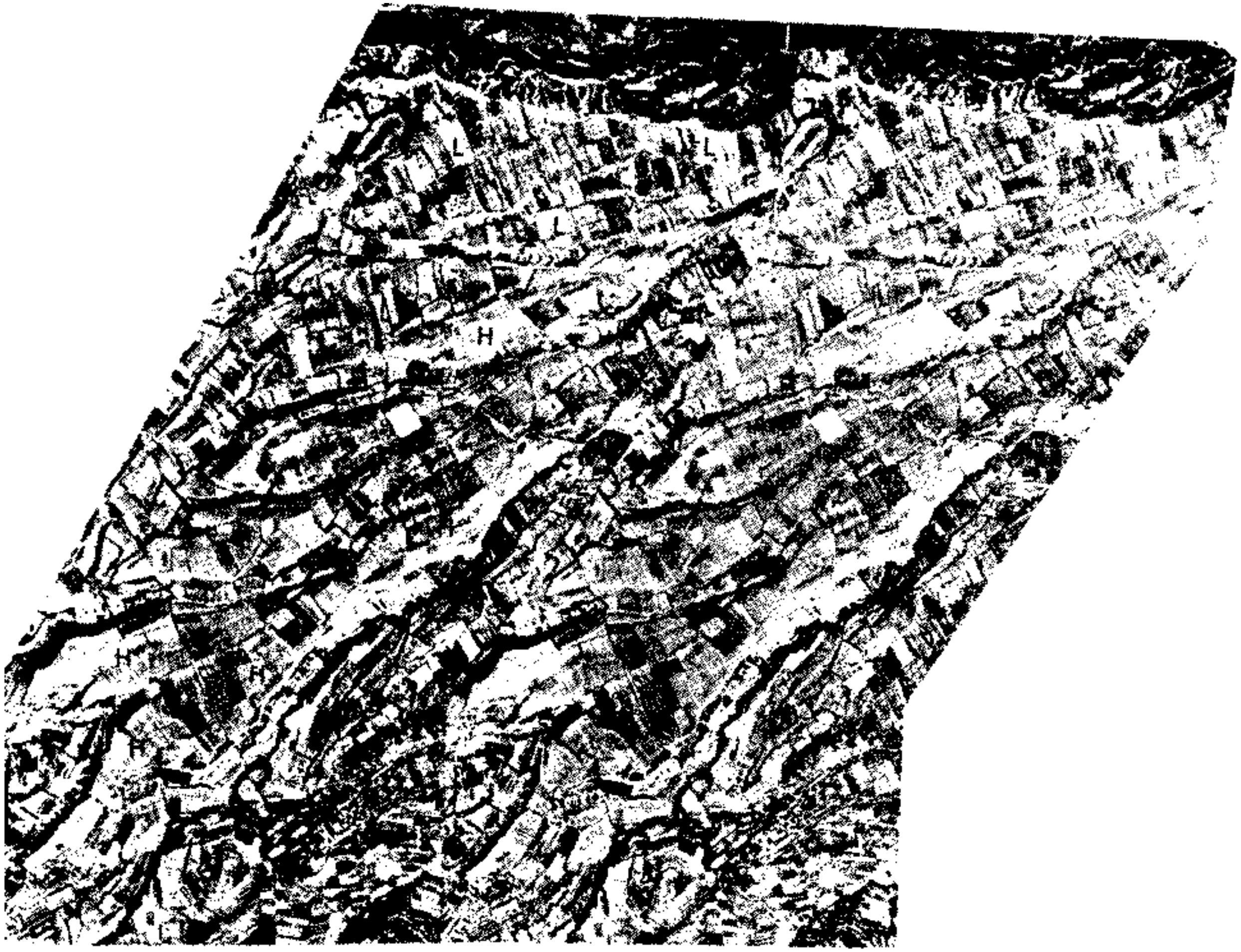

Photo 3 - The stereogram shows two levels of glacis formation which are a good source of granular materials. The lobate termination of the top level (H) is indicative of a thick liquid flow (sheet flood) over the lower level (L). The preserved smooth and gently inclined surface and the light phototone indicate the characteristics of the landform and the existence of coarse-grained granular materials.

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