

## EXPLORATION OF AGGREGATE MATERIALS WITH GEOMORPHOLOGIC AND GEOTECHNICAL TECHNIQUES

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#### PURPOSE:

A comprehensive exploration methodology is presented which involved the integration of remote sensing techniques, and geomorphological, and geotechnical studies to locate aggregate materials in the State of Louisiana. Landform analysis from aerial photographs along with geomorphic analysis of topographic forms has indicated the areas of promise which required further insitu investigations. Ground methods, employing both geotechnical and field sampling techniques have aided stratigraphic analysis and refined the image based expectations. Specific sites were identified, one in each region of Louisiana, and are used as examples to demonstrate the principles of exploration from broad scale mapping to site specific exploration.

**KEY WORDS:** Aggregates, image interpretation, terrain analysis, landforms, cone penetrometer, Louisiana, terraces

#### INTRODUCTION

Aggregates are rock fragments or naturally-deposited sands and gravels which might be combined to produce a mixture that can be used in construction. Existing geologic and soil maps have only general indications about environments in which aggregates may be found. The majority of known aggregates in the State of Louisiana are granular materials found as stratified sands and gravel deposits. Image analysis of remotely sensed data coupled with geomorphic and stratigraphic analysis, geotechnical exploration, and field sampling have provided a methodology of exploration for aggregates by designating prime areas for detailed study.

This effort describes a comprehensive exploration methodology which involves the integration of terrain analysis techniques, together with geomorphological, and geotechnical studies to locate aggregates in the State of Louisiana (Argialas *et al.*, 1992). The approach follows an "establish-refine" methodology: each phase establishes certain criteria for aggregate site selection which leads to the refinement of the selected sites of the previous phase. This involves a conceptual and spatial focusing from regional to site specific evaluation. The process is repeated until the final phase.

The first phase of exploration involved a statewide assessment of mining activities and analysis of small-scale topographic, geologic, and soil maps and aerial photographs and resulted in the determination of twenty-eight aggregate bearing environments in the State. The second phase involved landform analysis from various scales of aerial photographs and geomorphic analysis of topographic forms and has resulted in selection of twelve, and after

further refinement, four potential aggregate trends. The third phase involved field investigations, utilizing borings, surface trenches, and Cone Penetrometer soundings to determine the extent, overburden thicknesses, and potential value of the aggregate deposits. Within the scope of this study, four sites were thoroughly investigated (Argialas *et al.*, 1992).

#### METHOD OF PROCEDURE

A number of investigators have concluded that the most efficient approach to exploring for aggregates is the integration of remote sensing, insitu soil investigations and soil borings (Mintzer and Struble, 1965; Orr and Quick, 1971; Mathewson *et al.*, 1985). Image interpretation of aerial photos of a site prior to field surveys is the most efficient exploration approach because it focuses attention, in a systematic manner, on areas where aggregate deposits are mostly likely to occur. Thus field surveys can be conducted in those locations having the highest probability of occurrence of aggregates and hence exploration costs can be minimized.

The specific methodological steps of this study were:

1. Determination of aggregate bearing environments in the State through literature evaluation and analysis of topographic, geologic, and soil maps and small scale aerial photographs.
2. Conceptual modeling of the geologic processes that might have contributed to the deposition of aggregate materials.
3. Identification of a few potential aggregate trends through interpretation of large scale aerial images, examination of landforms,

- and geomorphic analysis of topographic forms.
4. Field investigations, utilizing borings and surface trenches, to determine the extent, overburden thicknesses, and potential value of aggregate deposits.
  5. Procurement and analysis of cone-penetrometer data to define the depth and distribution of the potential aggregate-producing strata.
  6. Convergence of evidences and final site evaluation for economic aggregate potential.

In order to accomplish these steps it was found necessary to segment the study in three Phases. Figure 1 presents an overview of the phases, tasks, work activities, and products of the aggregate exploration process. Phase 1 describes the Literature Survey and Regional Evaluation, Phase 2 describes the Landform Interpretation through Terrain Analysis, and Phase 3 describes the Selective Field Checking, Stratigraphic Mapping, and Cone Penetrometer Testing. The approach is one of "establish-refine": each phase will establish certain criteria for aggregate site selection which will lead to the refinement of the selected sites of the previous phase; this process will be repeated until the final phase. This involves a conceptual and spatial focusing from regional to site specific evaluation.

#### Phase 1: Literature survey and regional evaluation

Aggregate deposition follows certain physical laws. Aggregates are expected to be found only under certain geologic conditions and are not likely to be found occurring under others. It is therefore important that relevant geological processes be established and related to patterns of aggregate deposition. To accomplish the above goals, a literature survey was conducted of all available topographic, geologic, geomorphic, geotechnical, hydrologic, and pedologic reports and maps to formulate the regional picture. Furthermore, an inventory of the location, origin, morphologic history and composition of previously located deposits was made to provide means for conceptual and spatial interpolation in search of new deposits. Files searched were those of the Louisiana Department of Transportation and Development, the Louisiana Geological Survey, the U.S. Army Corps of Engineers, and the Soil Conservation Service.

After a thorough perusal and study of the available maps, reports, and data regarding the previously located aggregate deposits, a regional concept was formulated. The concept forms a general impression as to the nature of the soil and landform conditions. The State's soils were analyzed with respect to their geologic and geomorphic origin by noting the arrangement of physiographic units and the materials or layered sequences underlying them. As a result of Phase I

studies, twenty eight aggregate bearing trends were identified for further analysis (Argialas *et al.*, 1992).

#### Phase 2: Landform interpretation through terrain analysis

Interpretation of landforms using aerial photographs was achieved in two scales of analysis: regional and detailed. The regional analysis employed small-scale aerial photographs (approximately 1/135,000 scale) and the detailed analysis employed medium (approximately 1/65,000 scale) and large scale aerial photographs (approximately 1/20,000 and larger scales).

The methodology of identifying aggregate materials on aerial photographs was based on the interpretation and mapping of landform units and features such as Pleistocene terraces, valley train deposits, and Holocene flood plains. Landforms are the key elements in the exploration of aggregates from aerial photographs because they indicate the development of constructional geologic processes of soil erosion, transportation and deposition. The various landforms in which aggregate deposits may occur in Louisiana are of fluvial type and include stream terraces, fluvial outwash, meander belt deposits, point bars, abandoned channels, and braided stream channels.

Landforms were studied through the terrain analysis approach. Terrain analysis is the systematic study of visual and physical elements relating to the origin, morphologic history, and composition of landforms (Way, 1978). It is the approach used by photointerpreters in analyzing soil patterns from large scale photography. It is based on the principle that similar environmental, geologic, topographic, and climatic conditions create similar landscape patterns.

The visual and physical elements employed during stereoscopic terrain analysis were the pattern elements and included topography, drainage patterns, gully characteristics, vegetation, and land use. These pattern elements provide the framework within which the visual impression of landforms was examined and recorded. When a specific landform type was identified, the soil types was subsequently inferred because most of the landforms exhibited specific range of soil types and textures.

Besides mapping landforms that could potentially bear aggregate materials, one can also identify landform features that have potential for aggregate materials. Landform features having a high potential for aggregate materials include active and abandoned point bar deposits, stream terrace deposits, abandoned channels, and meander belt deposits (Frost, 1945). Point bars are typically composed of distinct layers that have an upward grading sequence, that is, gravel, the coarsest material can be found at

the base and grade upward through sand, fine sand, clay and other floodplain deposits (Autin, 1985; Schumm, 1977). As a river continues its lateral movement within its meander belt, meander loops may be cut off or abandoned, and therefore act as storage areas for coarse grained point bar deposits. Other areas with a high potential for aggregate materials are simple valley fill and the confluences of channels and tributaries with high bed load. These areas tend to have no distinctive surface expression and therefore are difficult to identify on aerial images. Valley fill occurs when the coarsest materials are deposited within the deepest parts of the channel and the channel is subsequently covered by finer floodplain deposits as the channel is abandoned. Deposits at confluences are the result of a high bedload, high velocity stream meeting a low velocity stream. The low velocity stream is unable to transport the material of the high velocity stream and thus the bedload material will be deposited at the location where they meet. Areas that separate landform units also has a potential for aggregate materials. As stream flows from one landform to another the gradient between landform changes. As a result of these gradient changes, the competence of the streams are reduced causing deposition to occur in their channels.

Landform interpretation was performed using the following steps for each trend (Argialas *et al.*, 1992):

- (1) Review and description of the soil composition of the trend using soil survey and other relevant published information.
- (2) Review and description of the geology of the trend from information found in parish geology bulletins and other relevant journal articles.
- (3) Review and description of the geomorphic origin and history of the trend from information found in parish geology bulletins, journal articles and other published papers.
- (4) Stereoscopic analysis of photographs using the terrain analysis approach.
- (5) Identification and mapping of landforms based on the observed pattern elements.
- (6) Correlation of observed landform with geologic unit, soil unit, and geomorphic origin and history to determine if any relationship exist. Any correlation would allow further refinement of the aggregate trends.

Mapping of landform boundaries was based on the following criteria:

- (1) identification of any drastic or sharp change in topographic gradient, drainage pattern, vegetation and landuse;
- (2) boundary lines between geologic units if available;
- (3) boundary line between soil units if available or the soil composition of the aggregate trends; and

- (4) the existence of special landform features such as meander scars and point bars.

Landform interpretation and mapping included careful scrutiny of areas where significant changes of the pattern elements take place for these are directly related to locations where changes in landform and soil patterns occur. Often these changes occur at breaks in slope. These slope changes are generally accompanied by change in soils and subsurface sediments. Change in topographic gradient of trends is a good indication where deposition would have occurred. Many of the important gravel-bearing strata in Louisiana occur beneath landforms constructed in aggradational sedimentary environments. The density of drainage patterns generally is related to the relative permeability of surface materials. Distinctive differences in drainage patterns and dissection are associated with the Pleistocene terraces of southeastern Louisiana (Mossa and Autin, 1989). The boundary line between geologic units usually indicates different geologic material that are suitable or not suitable for aggregate. Similarly, some soils are good indicators of aggregate potential as the soils are the result of weathering of the underlying materials or deposition. Light soil tones on B&W images are indicative of coarse-grained, well-drained soils. In Louisiana, settlement patterns often follow trends of well drained soils associated with sand and gravel extraction. Vegetative cover can be indicative of granular materials, because some tree species prefer well drained soils (e.g., orchards and pine trees). These criteria were used separately or in combination in order to identify locations that may have a potential for aggregate material.

#### Phase 3: Selective field checking, stratigraphic mapping, and cone penetrometer testing

Selective field checking and stratigraphic mapping was carried out to confirm and/or revise the image interpretation results and to evaluate the surface characteristics of the aggregate trends. The reconnaissance stratigraphic study has employed a Giddings hydraulic probe and it was conducted at four sites to gather information on the geometry of the deposits, general textural trends within the deposits, and overburden characteristics (Mossa and Autin, 1989). Refined aggregate location maps, stratigraphic maps and cross sections were prepared to show the lateral distribution and depth of the aggregate deposits and associated overburden (Argialas *et al.*, 1992).

To further refine and compliment the previous results Cone Penetrometer Testing was employed. The cone penetrometer can be used to classify the different soil strata by employing the recorded data from the field tests. The data recorded from the field test were (1) tip resistance, (2) frictional resistance, and (3) friction ratio. The tip resistance is defined as the resistance offered

by the soil to the tip of the penetrating cone. The friction resistance is the resistance measured along the sleeve of the cone. The friction ratio is defined as the ratio between the sleeve friction to the cone resistance. These values vary with the type of soils like clay or sand or a mixture of both, the consolidation levels i.e. normally consolidated or over consolidated (in clays) and the relative density (for sands). Several studies were conducted using this equipment in Louisiana and several classification charts have been developed for identifying the soils based on these data and some of these charts are used in the present classification study.

Two sites were selected to minimize exploration costs. The sites were selected at locations where confirmatory information or more detailed information was required. The cone penetrometer sounding locations were selected to complement the hydraulic probe data. The data from the cone penetrometer data could confirm, or refine the findings of image analysis and stratigraphic mapping.

Data related to location of aggregate materials is obtained through an iterative process involving integration of information extracted during all phases of the study. The convergence of information from the smallest to the largest scale of analysis and from image data to geotechnical data reinforces the interpretation made at each level. All data from image analysis, stratigraphic survey, cone penetrometer borings, and field samples were integrated and correlated leading to the final assessment of the aggregate deposits and their textural composition. Final maps were made to show the location of the four aggregate trends on 7.5 minute topographic base maps. Final profiles were drawn to show the textural composition of the aggregate deposits and their associated overburden (Argialas *et al.*, 1992).

#### CONCLUSIONS

Aggregate material deposits which can be processed economically for construction materials are an important resource for the State of Louisiana. This need together with the shortage of aggregates in the State necessitated a thorough study in development of an exploration methodology for mapping the availability, location, and extent of aggregate materials. This effort described a comprehensive exploration methodology which involved the integration of terrain analysis techniques, geomorphological, and geotechnical studies to locate aggregates in the State of Louisiana. Landform analysis from aerial photographs along with geomorphic analysis of topographic forms has indicated the areas of promise which required further insitu investigations. Ground methods, employing both geotechnical and field sampling techniques have aided stratigraphic analysis and refined the image based expectations.

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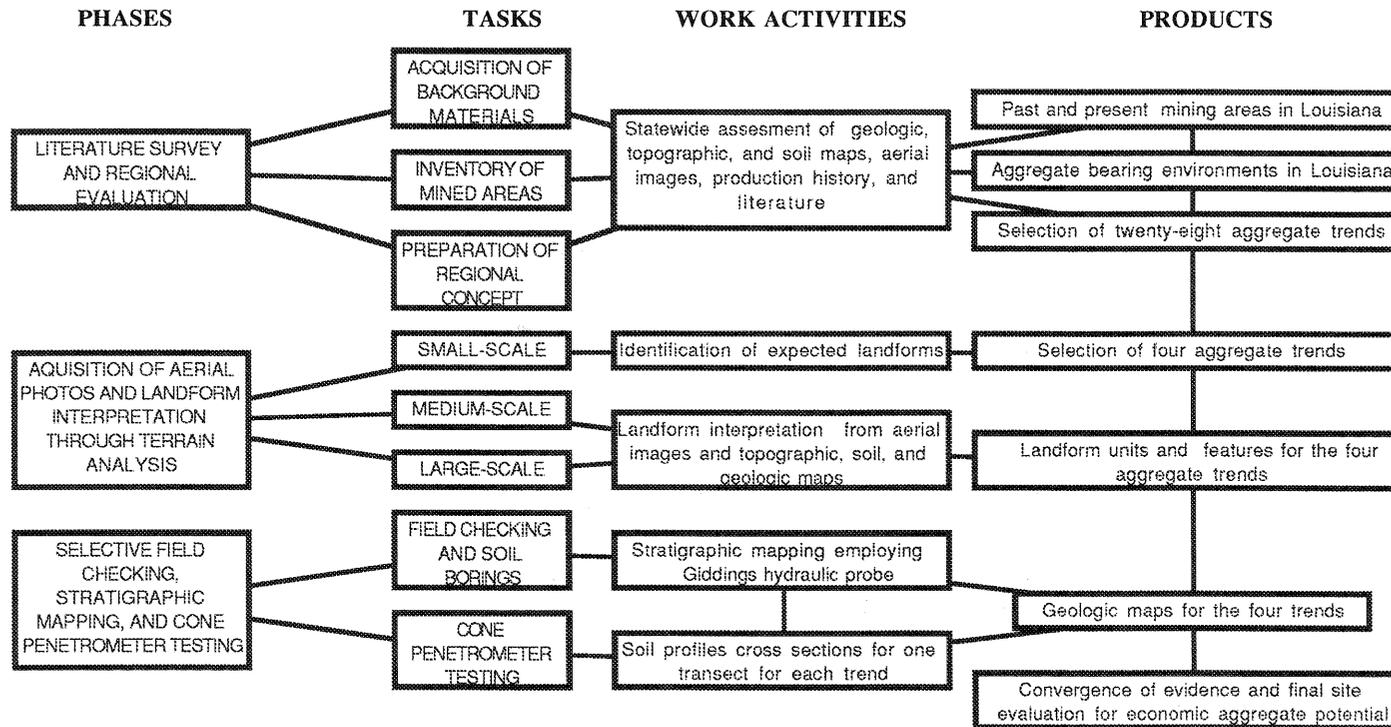


Figure 1. An Overview of the Phases, Tasks, Activities, and Products of the Aggregate Exploration Process.