# Large-scale engineering geological map of the Patras city wider area, Greece

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**Abstract:** The preparation and compilation of an engineering geological map of Patras city wider area, at a scale of 1:5,000 is presented, prepared as a part of a thorough geotechnical study of the broader area of the city for urban planning purposes. In this map, eleven (11) engineering geological units were grouped, based on their lithostratigraphy, physical conditions and geomechanical properties. More specifically, two (2) lithological types of man-made deposits (recent and historical fills) of small thickness, which cover at some places the Quaternary formations and Plio-Pleistocene sediments, were distinguished. The recent Quaternary formations were grouped in five (5) lithological types, namely marshy deposits, coastal sands, river bed deposits, Holocene deposits, and the weathering mantle of older formations. The old Quaternary formations were classified as alluvial, diluvial and Pleistocene deposits, while the basement of the area consists of Pliocene sediments. Of the above lithological types, the fill materials and the Holocene deposits constitute the most difficult ground of the city area. The former are loose materials of mixed phases up to 8m thick, while the latter, with a thickness up to 35m, consist of soft, clay to silty clay materials (ML, CL), with SPT 'N' values ranging from 2 to 28 and generally less than 10. In places they include thin lenses of silty sands and gravels (SM, GW-GM and GC). So, these materials need special treatment in the case of various foundations. Also, the rest of the Quaternary formations (alluvial, diluvial and Pleistocene types), with a thickness of up to 90m and SPT 'N' values from 4 to 50, are of a high heterogeneity and non-uniform geomechanical behaviour and so they should be studied in detail for every case of human activity. Finally, the Pliocene sediments consist of the marly bedrock of the city area, with SPT 'N' values from 20 to more than 50 and a thickness more than 300m. They outcrop mostly in the area surrounding the town, and cause, in some places, instability phenomena.

**Résumé:** La préparation et la constitution de la carte technicogeologique de la ville de Patras et de ça banlieu, a l' echelle 1 :5.000, est présentée dans ce travail, comme une partie de la recherche géotechnique etendue de cette région pour des raisons d'urbanisation. Dans cette carte on a distingue onze (11) unités technicogeologiques (types lithologiques), selon la lithostromatographie, les conditions physiques mais aussi les propriétés geotechniques des formations.Plus en détails, deux types lithologiques des dépôts d'origine humaine ont étés distingues (dépôts récentes et historiques) qui couvrent localement, a une faible épaisseur, les formations du Quaternaire et les sédiments du Plio-Pleistocene. Les formations récentes du Quaternaire ont étés groupees dans cinq (5) types lithologiques c'est a dire : les dépôts marécages, les sables cotieres, les depots de l' Holocene et la nappe d'altération des formations anciennes. Les formations anciennes du Quaternaire ont étés classifiquees aux alluvions, dilluvions et dépôts Pleistocenes tandis que les formations du substratum se constituent de sediments du Pliocene. Parmi les types lithologiques ci-dessus, les dépôts récents et les dépôts d' Holocene constituent, le terrains les plus difficiles de la région de la ville. Les premiers sont des matériaux relâches des phases mixtes avec une épaisseur de 8 mètres, tandis que les formations de l' Holocene avec une epaisseur jusqu' a 35 metres, se sont constitues aux matériaux argileuses moux (ML, CL) avec de valeurs 'N' SPT entre 2 et 28 mais généralement au dessous de 10. Dans certains places ils comprennent des lentilles minces des sables argileuses et des graviers (SM, GM-GM, GC). Par conséquent ces matériaux doivent être traites spécialement au cas des fondations diverses. En plus, les autres dépôts Quaternaires (alluvions, dilluvions et depots Pleistocenes) avec une epaissens jusqu' a 90 mètres et de valeurs 'N' SPT entre 4 et 50, se caractérisent d une grande heterogeneite et d un comportement geomecanique irregulier et par conséquent ils doivent être études en détails avant chaque activité humaine. Enfin les sediments du Pliocene du subsratum marneux de la ville de Patras, qui ont de valeurs 'N' SPT entre 20 et plus grandes de 50, et une épaisseur plus de 300 m, affleurent surtout aux collines autour de la ville et provoquent aux certains places des phénomènes d' instabilite de la pente.

**Keywords:** Geology of cities, seismic risk, field and laboratory tests, engineering properties, eng. geology map.

## INTRODUCTION

Modern man typically develops cities without taking precautionary measures for natural hazards. Despite this he holds the scientific documentation on the regions where geological or other type of hazards are visible. So, densely populated urban centres are often founded on steep slopes, or on poor soil conditions, even in areas with high seismicity.

Exact knowledge of the geological-geotechnical conditions of an urban area is necessary to provide basic essential information of the ground condition to the local authorities, engineers and contractors. This necessary information also constitutes the basic concept for the evaluation both the geological hazards, which are encountered in the area in question, and the dynamic response of the construction in the case of seismic activity. The latter data are urgently required in countries such Greece, where the seismicity in the region around is intensive. For this purpose, a large scale engineering geological map was prepared for the urban areas of Patras city, with a thorough presentation of surface and subsurface conditions, up to a proper depth, and this constitutes a basic tool for a complete geotechnical study.

Patras is the capital of Achaia prefecture and a major centre of population and industry in Western Greece. This is the third largest city of Greece, but also one with high seismic risk, as it is very close to centres of high seismicity (Corinthian and Patraikos gulfs, Ionian Sea). Patras is a vibrant city with a population of about a quarter of a million and its harbour is a significant commercial and tourist gateway of Western Greece and its cultural contacts with Italy have played an important role in the continuous development of the city.

Patras is located in the northwestern part of Peloponnesus, in a narrow belt of low land immediately to the west of Panahaikon Mountain (Figure 1). Due to its geographical position, Patras serves as the main transportation centre between the European Union and the countries to its East.

This paper evaluates the engineering geological conditions in the wider area of the city as a part of a systematic survey included both engineering geological mapping and borehole sampling as well as in situ and laboratory tests. The results of the study were evaluated with regard to foundation conditions and they provided a useful guide to urban planning related to residences and the construction of technical works.


**Figure 1.** Location map of Patras and its metropolitan area.

## GEOLOGY AND HYDROGEOLOGICAL BEHAVIOUR OF THE FORMATIONS

The wider area of the city of Patras is founded on Quaternary deposits and Plio-pleistocene sedimentary rocks and unconsolidated soils. They include marshes, coastal sands, fluvial sands and gravels, Holocene deposits, and weathering mantle of Plio-pleistocene sediments, as well as alluvial and diluvial deposits. In general, the total thickness of the Quaternary deposits exceeds 80 meters while they can be grouped from the lithological and hydrogeological point of view, as follows:

- Marshy and Holocene deposits as well as weathering mantle of Plio-pleistocene sediments. They are fine-grained materials (clayey silts, sandy clays, sandy silts with sparse grits, gravels and cobles with small percentage of clear sand). Marshy deposits are encountered in the north part of the city and they have a restricted surface development, while the weathering mantle of Plio-pleistocene sediments shows a rather extensive surface development in the eastern part of Patras. Finally, the Holocene deposits cover a wide belt of the western part of the city, with considerable thickness. In general, these formations are of low to medium hydraulic conductivity and only in some cases can be characterized as impermeable, with a thickness reach the 80 meters.
- Coastal sands, river bed deposits. They consist of loose coarse-grained materials (sands, grits, gravels, cobles and pebbles) with a very small percentage of fines (clays and silts). They are highly permeable while their maximum thickness is about 20 meters.
- Alluvial and fan (diluvial) deposits. They are mainly loose mixed phase materials (cobles, gravels, grits, medium to coarse sands and fines). The latter consist of clayey silts to sandy silts. They are encountered in the south and southeast part of the city as well as in surroundings. They are characterized as being of medium permeable to permeable materials with a thickness ranging from 6 to 80 meters.
- Plio-pleistocene sediments outcrop around the central part of the city, where the morphology is gentle with low hilly elevations. They can be subdivided into two distinctive horizons:
  (a) An upper coarse-grained horizon consisting of brownish-yellow clayey marls with silts, sands, gravels, and pebbles usually 50-100 meters thick. (Rozos, 1989; Koukis & Rozos, 1990). In some places the coarse-grained materials dominate and occur in the form of conglomerates with a medium to high degree of hydraulic conductivity and a thickness of 4 to 10 meters (Koukis et al, 2001).
  (b) A lower with fine-grained materials consisting of dark grey silty marls and sandy silts. Lateral changes of the lithological units in this horizon are frequent; also an increase of the percentage of its coarse-grained materials is observed in some places near to its upper part were conglomerate benches are created of medium diagenesis. This horizon is characterized by low to medium hydraulic conductivity and has a thickness greater than 150m.
- As regards the bedrock which outcrops in the mountainous area east/southeast of the city, it is dominated by the Olonos-Pindos geotectonic zone consisting of schist-sandstone-chert formations (Jurassic to Cretaceous), thinly-bedded limestones (Upper Cretaceous) and materials of the transition zone from limestone to flysch sediments as well as flysch sediments. They are characterized by medium to high secondary permeability and only in the places where thin alternations of siltstones and fine sandstones of flysch or schists and cherts occur, the hydraulic conductivity is low to very low.

Ground water measurements obtained from exploratory boreholes, have shown a general fluctuation of the groundwater surface in the urban area. Close to the coastal part of the city, which is dense populated, depth to the saturated zone ranges from one to 10 meters, while in the other parts from 10 to 30 meters.

## TECTONIC REGIME

The Patras area falls within the Corinth–Patras rift zone, which is 100 km long and trends WNW-ESE across the Hellenic Mountain Range, approximately perpendicu1ar to its structura1 arrangement. In reality, as shown in Figure 2, the rift zone possesses a comp1ex pattern with two WNW trending gardens, namely the Corinth graben in the east and the Patras graben in the west, which are connected with the NNE-SSW Rio graben (Doutsos & Kokka1as 2001). This rift zone accommodates most of the extension associated with the active subduction of the African p1ate underneath the Eurasian p1ate, and has been recognized as one of the most rapid1y deve1oped inter-continenta1 rifts in the Mediterranean region. Onshore and offshore norma1 fau1ts in the rift zone trend WNW-ESE with a maximum surface trace of about 25 km (Koukouve1as & Doutsos 1996; Stefatos et a1. 2002; Moretti et a1. 2003). The fau1ts dip north, typically at moderate ang1es ($50^0$-$60^0$) and rare1y at a high ang1e ($60^0$-$80^0$). The rift was developed in two stages (Ori 1989; Doutsos & Piper 1990). The first stage was characterized by a shallow fault-controlled basin, which was filled with fresh water sediments (1,000-2,000 m thick). The second stage was characterized by fan de1tas and coarse-grained terestria1 sediments with a maximum thickness of 1,200 m. Several offshore and onshore studies undertaken on the Patras graben (Doutsos et al. 1987; Ferentinos et al. 1985; Zelilidis et al. 1988) and Corinth graben (Kontopoulos & Doutsos 1985) have shown that the mean trend of the fau1ts is NE-SW and NW-SE, respectively.


**Figure 2.** Simplified tectonic map of Patras and Corinth gulf (according to Doutsos & Kokkalas, 2001).

The fault trace map of the broader area of the city of Patras is shown in Figure 3, based on systematic fieldwork and air photo interpretation (Koukis et al. 2005). The main trend of the faults in this map is NE-SW. The normal fault in Agia Triada, a southern suburb of Patras, which was reactivated during the 1989 earthquake, belongs to this group of faults. Another main group with a dominant NW-SE trend crosses the urban area has been recorded between the city port and the Glafkos River. Along the main fault traces, relatively small ground movements (cracks on road pavements and buildings, subsidence etc.) are periodically observed (Figure 4).

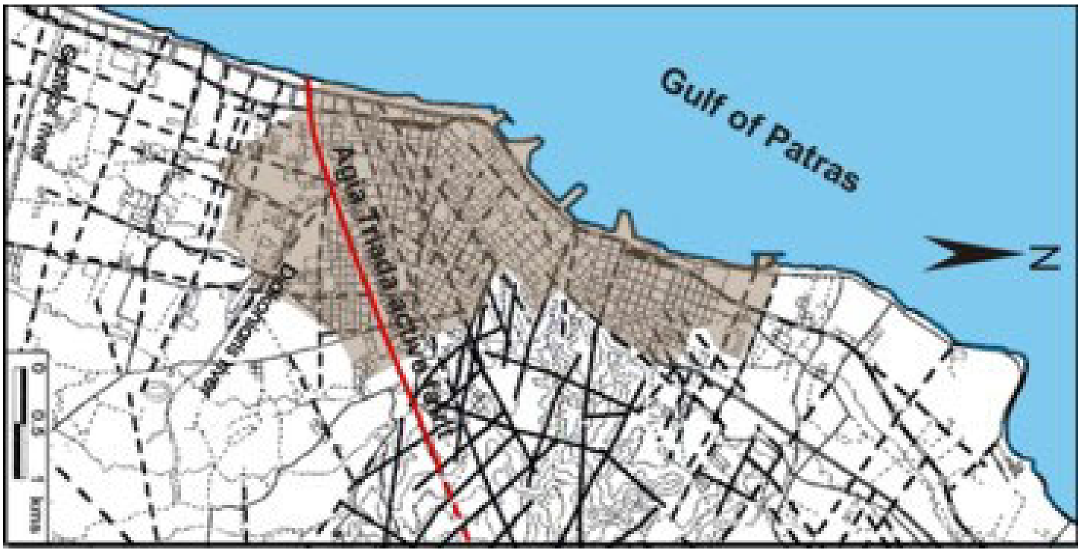


**Figure 3**. Fault trace map of the city of Patras (Koukis et al. 2005)

## SEISMICITY OF THE AREA

The high seismicity of the area is closely related to the above mentioned fault tectonics and to existence of grabens with a recent geodynamic evolution. Although the last century the seismic activity in the Patras area was relatively low, there are evidences from historical records that very strong earthquakes have occurred (Papazachos & Papazachou 1989). The dynamic loading that applied on the various geological formations encountered in Patras area by shallow and of high magnitude earthquakes, apart from the direct results on the constructed environment, may also activate landslides, rock falls, and liquefaction. The manifestation of these secondary phenomena is also important from a geotechnical point of view, as they affect residential areas and various industrial works.

In 1989 and 1993 the city was struck by earthquakes of small to moderate magnitude (Ms=4.8R and 5.4R respectively) which cause serious structural damages to new multi – storey buildings, while surface ruptures have been noted to reactivate existing faults traversing the city (Koukis et al. 2005). The seismic data evaluation indicates that an area of 100 km around the city may expect earthquakes of magnitude of 5.9 R each 10 years and a magnitude 6.6 R or more every 50 years. The expected bedrock peak ground acceleration of seismic bedrock, at 90% probability of exceedence within 50 years, ranges from 0.20 g to 0.33 g (Sokos 1998).

Finally, a database operated by the Seismological Network of Patras University (PATNET), which includes all known active (Holocene movement) faults with a mapped length of > 2.5 km, has led to identification of three different categories as the most critical for future events (Tselentis, et al. 1995).

(a) Faults within 10 km of the city or tracing beneath the city, with a potential magnitude of 4.5 R or more;
(b) Faults within 50 km of the city, bounding the Gulf of Patras, and with a potential magnitude of > 5.5 R;
(c) More distant faults with the potential of higher magnitude events generating surface waves affected the city area, boun the Gulf of Corinth.


**Figure 4**. Agia Triada fault trace, (a) in a basketball field, (b) in the coastal part of the city ring road.

# ENGINEERING GEOLOGICAL CONDITIONS

The Engineering geological behaviour of the formations that constitute the foundation ground of the city and the engineering geological characteristics of the various types, are detectable in lithostromatography, were studied by using the available extensive geotechnical database (Koukis et al. 2005). This is a relational geotechnical database system interplayed with GIS, including information obtained from a large number of exploratory boreholes, cone penetration tests (CPT) and cross-hole seismic prospecting.

A multipurpose, large-scale engineering geological map was compiled at an original scale of 1:5,000, based on the origin, relevant age, composition, physical state and engineering geological characteristics of each of the geologic formations.

In this map (Figure 5), the formations are grouped into distinctive lithological types:

- Two lithological types distinguished for the man-made deposits (recent and historical fills), which locally cover the Quaternary formations and Plio-Pleistocene sediments.
- The recent Quaternary formations were divided into five lithological types: marshy deposits, coastal sands, riverbed deposits, Holocene deposits and weathering materials (including landslide debris). These are generally loose, unconsolidated soils with a maximum thickness of about 10 m.
- The older Quaternary formations were grouped into two lithological types: alluvial and diluvial (fan) deposits, including variable formations with a thickness from 6 to 80 m.
- Plio-Pleistocene sedimentary rock of the geological basement of the Patras city area distinguished as two lithological types: the Pleistocene formations and the Pliocene sedimentary rock, both of which which have thicknesses exceeding 300 m, and which occupy a large area to the east and northeast of the city.

Foundation soils of the greater city area were separated into eleven (11) lithological types, described below:

## *Man-made deposits (two lithological types)*

### *Recent fills*

Recent earthfills including coarse grained soils and other materials as stones, mortar and other construction debris, deposited from modern demolition, and located mainly along the coastal zone of the city

### *Historic materials*

The unit includes recent historic fill – the so-called historical layer – the major part of which consists of coarse grained soils, most of which contain stones, ceramics, mortar and other demoliton debris from ancient buildings.

The above man-made deposits usually cover the central part of the city with a maximum thickness of 10m and they constitute foundation soil of poor geotechnical characteristics, which, depending on its thickness, must be removed or improved.

### *Recent Alluvial formations (five lithological types)*

#### *Marshy deposits*

This lithological type consists of dark organic soft clays (CL) and silts (ML-CL) with low bearing capacity and of high compressibility. The unit is located in two rather restricted areas near Milichos River in the northern borders of the city, and with a typical thickness of 5-10 meters.

#### *Coastal sands*

Loose coarse-grained materials, consisting of sands, grits, gravels and cobles. They cover a 20 to 60 meter-wide zone along the beach. Most are poorly-graded units with high porosity, and a typical thickness of 7-15 meters.

#### *Riverbed deposits*

Loose, coarse-grained formations containing gravels, sands, grits and cobles, as well as clayey silts in a rather small percentage. Their thickness is connected with the class of the hydrographic axis, which accommodate them, but generally in the riverbeds, where they are estimated at typically from 10 to 20 meters in thickness.

#### *Holocene deposits*

This lithological type consists of loose deposits, which are formed by grey silt and soft clay, with intercalations of sand and gravels. Fully saturated formation, of medium compressibility and low bearing capacity.

The materials of this type occupy the lowland plain near the coastal zone of the city with a thickness between 12 and 40m.

#### *Weathering materials mixed with landslide debris*

The weathered mantle of Pliocene sediments consists of clayey silts, sandy silts, sands and small fragments of marl and sandstone. In many cases, these materials are mixed with remoulded masses of Pliocene hillside sediments displaced by due to creep, landslides and earth flows, all of which are frequent occurrences in the wider metropolitan area. These materials are mainly clayey marly and sandy materials with low residual shear strength characteristics.

The above formations, as a whole, constitute difficult foundation ground, with a thickness of 1 to 5 meters in the cases of weathering mantle without any other material and from 10 to 20 meters in the case of the mixed phases of hillside debris.

### *Old Alluvial formations (one lithological type)*

#### *Alluvial deposits*

This ground underlies extensive lowland building development and they consists of fine-grained materials, such as brown, brownish-grey, brownish-red clays and silts with intercalations of silty sands, and sands, along with grits and gravels. The percentage of the latter is generally small and of variable character, changing from place to place.

These heterogeneous units are made up of loose to semi-coherent materials of low to medium plasticity and hydraulic conductivity, and display facies changes, both horizontal and vertical, a fact that induces non-uniform geotechnical behaviour.

This behaviour, in combination with the nature of the materials, the active tectonics of the area and the human activities, leads to several types of ground failures, either as local settlements or as wider subsidence in the area between Diakoniaris and Glafkos River (up to 0,5m), and is due mainly to extraction of water from wells.

This lithological type, is also found beneath the recent and historic fills of the city center, and gains a maximum thickness of about 60m.

### *Diluvial deposits (one lithological type)*

#### *Fan deposits*

These unconsolidated soils are encountered mainly in the northeastern (Xaradros and Milichos rivers) and at the southern part (Diakoniaris and Glafkos Rivers) of the mapped area. They consist of coarse-grained materials, such as gravels, cobles, sands, and sandy gravels, with a small percentage of fines. The latter, mainly clayey silts and silty sands can be found either mixed with gravels or as distinctive lens-like horizons with thicknesses of 4 to 6 meters. They show low plasticity and medium cohesion. On the other hand, the coarse-grained materials (gravels and cobles), which dominate in the upper horizons, occur with a dominant size of 15-20 cm, are of limestone, or chert origin and usually characterized by a medium diagenesis, heterogeneity, and also a non-uniform but generally good geotechnical behaviour.

This lithological type, which shows horizontal pseudo-bedding, explaining its cohesion and low hydraulic conductivity, while its geotechnical behaviour is diminished by its percentage of fines, the grain distribution of the coarse particles, and the arrangement of the various lithological units. The typical thickness ranges from 6 to 50 m.

## *Plio-Pleistocene sediments (two lithological types)*

### *Pleistocene formations*

They are of terrestrial to fluvial origin and usually overlie the marly bedrock. They consist of brownish-red to brownish-grey or brownish-yellow silts, sandy silts and clays, with intercalations of sands, clayey-silty sands, silty sands, with or without cohesion, and coarse-grained materials such as gravels and cobles.

In areas of slight hillside inclination this constitutes a relatively thick weathering mantle varying from red clayey silts, gravels and cobles.

These mixed phases of Pleistocene deposits usually show low cohesion, but in some places (near the top of hills), the coarse-grained members gain high cohesion by way of their psammitic cement and they appear as benches of conglomerates with a thickness of 4 to 10 meters.

Their usual total thickness is estimated from 8 to 40 meters, but in some places can reach up to 90m.

### *Pliocene sediments*

River – lacustrine to tidal lacustrine and/or marine sediments, consisting of grey, clayey-silty marls, marls, calcitic marls, fine to coarse-grained sands with various degree of diagenesis, as well as mixed phases of the above sediment types. Small lenses of semi-coherent conglomerates with a thickness of up to 5m are also found in the upper horizons, while in the sparse gravels and cobles also encountered in the lower members, the percentages of which decrease with depth.

These Pliocene units form the marly bedrock of the city, and are, as a whole, are characterized as good weathered materials, with medium to high cohesion, and low hydraulic conductivity. In general, the lithological, engineering geological, and hydrological conditions favour the manifestation of landslide phenomena, such as creep, rotational slides, and earth flows. These geologic constraints occur mainly on hill slopes, where human activities of rapid urbanization are vigorous.

Their total thickness is estimated to be as much as more than 200 meters.

Table 1 summarizes the range of the laboratory and in-situ test values, including their description and their estimated thickness. for the most important lithological types described above, regarding their significance as foundation ground in the dense populated part of the city,

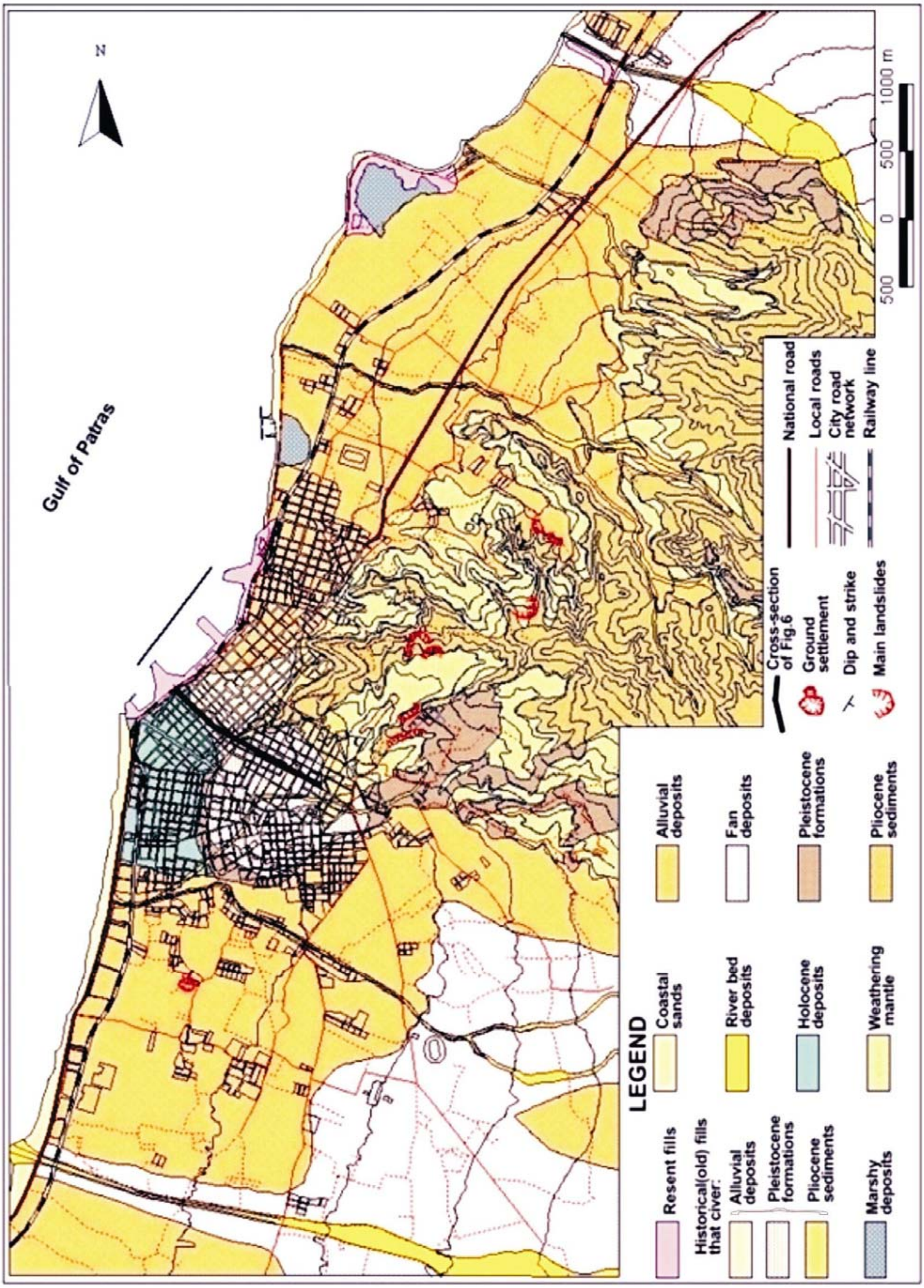


**Figure 5.** The engineering geological map of Patras city metropolitan area.

**Table 1.** The main lithological types which manly involved in Patras city urban area as foundation ground.

| A/A | Lithological types | Description | Maximum thickness (m) | Main geotechnical parameters |
|---|---|---|---|---|
| | **Man-made deposits** | | 1 – 10 | |
| I | Recent fills | | | |
| II | Historical fills | | | |
| | **Recent Alluvial formations** | | 5 – 40 | |
| III | Marshy deposits | Gray to black gray soft clay (CL) and silts (ML, ML-CL) with organics | 5 – 10 | $N_{SPT}$<5<br>$q_c$<10kgr/cm$^2$ |
| IV | Holocene deposits | Gray silt and soft clay (CL) with intercalations of sands and gravels (GW-GM, GC). | 12 – 40 | $N_{SPT}$ = 2 – 28 (generally<10)<br>$s_u$ = 24 – 80 kPa<br>$\gamma_b$ = 17.5 – 19 kN/m$^3$<br>$C_c$ = 0.111 – 0.261<br>$e_o$ = 0.641 – 1.028<br>$q_c$<10kgr/cm$^2$<br>$V_s$ = 120 – 230 m/s |
| | **Old Alluvial deposits** | | 6 – 60 | |
| V | Alluvial deposits | Brown to brownish gray silty clay (CL, CH) and silt (ML, ML-CL) with intercalations of silty sand (SM, SM-SC) | | $N_{SPT}$ = 10 – >50<br>$q_u$ = 80 – 600kPa(generally <400kPa)<br>$s_u$ = 40 – 120 kPa<br>$\gamma_b$ = 19 – 21 kN/m$^3$<br>$\varphi_u$ = 15º – 30 º<br>$C_c$ = 0.085 – 0.220<br>$e_o$ = 0.385 – 0.850<br>$q_c$=10 – 40kgr/cm$^2$<br>$V_s$ = 200 – 400m/s |
| | **Diluvial deposits** | | 6 – 50 | |
| VI | Fan deposits | Brownish gray silt (SM, SC) and sandy gravels (GM, GP-GM, GW-GM, GW-GC) | | $N_{SPT}$: 30 – >50<br>$V_s$ = 350 – 800m/s |
| | **Plio-Pleistocene deposits** | | >300 | |
| VII | Pleistocene formations | Brownish gray silt (ML) and clay (CL, CH) with intercalations of sands (SP), clayey sands and gravels (SC, SM, SM-SC). | 8 – 90 | $N_{SPT}$ = 20 – >50<br>$q_u$ = 50 – 450kPa<br>$s_u$ = 30 – 150 kPa<br>$\gamma_b$ = 19 – 21.5 kN/m$^3$<br>$\varphi$ = 10º – 30º<br>$C_c$ = 0.050-0.285<br>$V_s$ = 200 – 550m/s |
| VIII | Pliocene sediments | Gray to brownish gray clayey marls (CL, CH, CL-ML) | >200 | $N_{SPT}$ = 30 – >50<br>$q_u$ = 100 – 650 kPa<br>$\gamma_b$ = 19.5 – 22 kN/m$^3$<br>$s_u$ = 70 – 150 kPa<br>$\varphi$ = 10º – 25º<br>$V_s$ = 250 – 700m/s |

$N_{SPT}$ = SPT values, $q_u$ = unconfined compression strength, $s_u$ = undrained shear strength, $\gamma_b$ = bulk density, $\varphi_u$ = undrained angle of friction, $C_c$ = coefficient of consolidation, $e_o$ = void ratio, $V_s$ = shear wave velocity, $q_c$: cone resistance.

The participation some of the above lithological types to the lithostromatography of the central part of the city, are shown in the cross sections of the Figure 6.

Cross-hole measurements of shear wave velocity ($V_s$) and cone resistance ($q_c$) from CPT tests are shown in Figure 7. It may be observed that in genera1 $V_s$ and $q_c$ increase with the increasing geological age of the lithological type and with depth for each type.

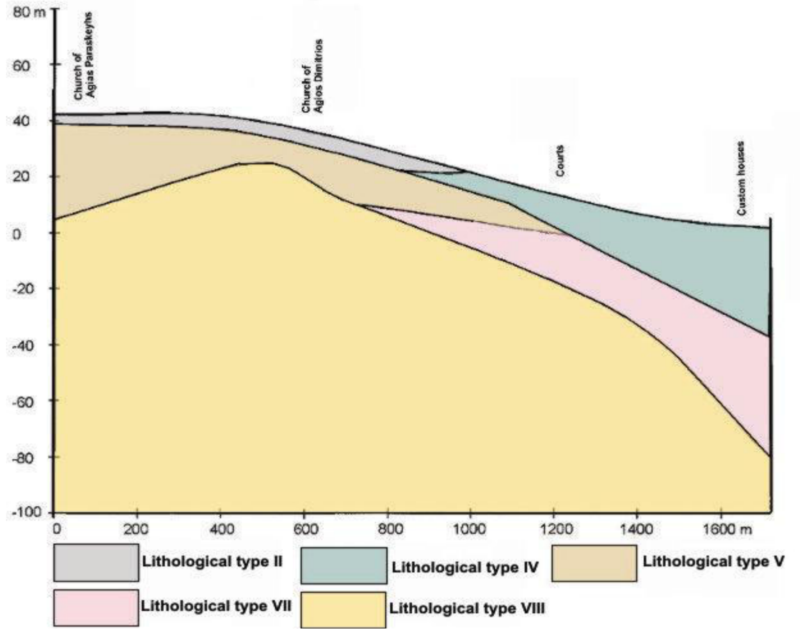


**Figure 6.** The engineering geological cross section T-T of a SE-NW direction, in the central part of the city.

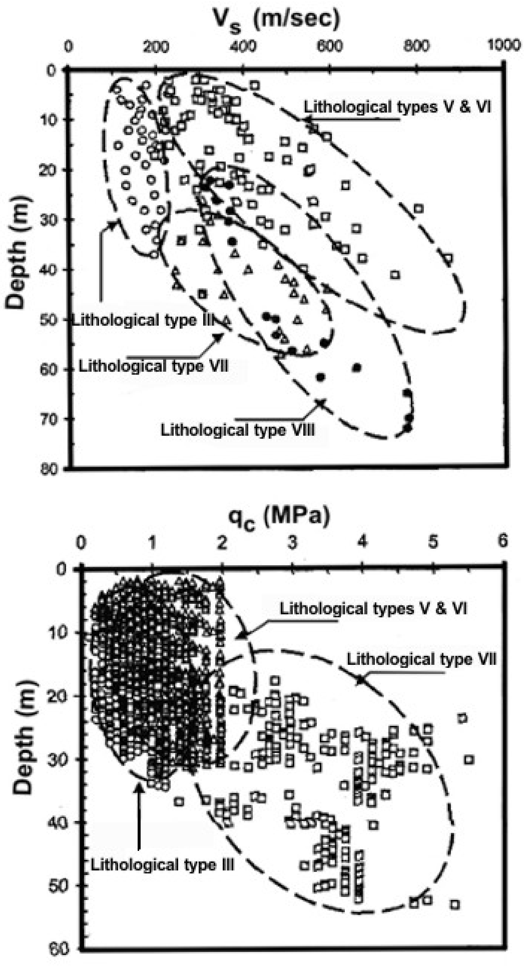


**Figure 7.** Correlations of shear wave velocity ($V_s$) and cone resistance ($q_c$), with depth for the main lithological types, in the city area (Koukis et al. 2005).

# CONCLUSIONS

The city of Patras is located in the near-field tectonically active grabens which are represented by active faults traversing the city. A large part of the city is founded on coastal lowlands, where the geological formations are loose, cohesionless deposits which constitute difficult foundation ground. Therefore, these engineering geological conditions, when combined with the active seismotectonic regime of the area (successive earthquakes), have led to serious damage to the constructed environment during past earthquakes. The large-scale engineering geological map of Patras is intended to reflect the prevailing geotechnical ground conditions of the city. This map also indicates the basic geological and geotechnical conditions prevailing in the metropolitan area for evaluation of the soil effect in regard to seismic-withstand ground-motion design parameters. In this map eleven (11) lithological types were distinguished as the typical foundation soils. For every one of the main lithological foundation ground types, detailed data are provided with regard to their physical condition, thickness, geotechnical characteristics, and shear wave velocity. This map was based on a combination of conventional geological mapping techniques and its geotechnical derivative information is considered to be useful for a preliminary, pre-site characterization planning level.

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