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THE ALLUVIAL PLAIN SEDIMENTARY FEATURES OF THE GUADALQUIVIR RIVER AT THE CARTUJA OF SEVILLE MONASTERY AREA

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Abstract. It is analysed influence of the Guadalquivir river dynamic over the Isla de la Cartuja, area where is placed the Cartuja of Seville Monastery, during fifteenth century. Seville-Isla de la Cartuja area is located in alluvial floodplain of the Guadalquivir River, then, floods were common events in this region. Nevertheless, from a town-planning viewpoint, Isla de la Cartuja is optimally located, in relation other nearby villages, because here, depositional and erosive processes related with dynamic of the river were balanced. Thus, only the biggest overflows flooded Monastery of Cartuja which, in spite of its proximity to the channel, needed the devasting contributions from adjacent tributaries and of runoff water to flood the monastery area.

Key words: Guadalquivir River, Floods, Isla de la Cartuja.

Resumen. Se analiza la influencia de la dinámica del rio Guadalquivir en el área de la Cartuja de Sevilla, donde se encuentra emplazado el Monasterio de la Cartuja que data del siglo XV. La Isla de la Cartuja se ubica en la llanura aluvial del rio Guadalquivir. Estuvo por lo tanto sometida a los procesos de inundación propios del medio. Sin embargo, y desde una perspectiva urbanística, la Isla de la Cartuja tiene una localización óptima respecto a otras poblaciones cercanas, puesto que los procesos erosivos y deposicionales relacionados con la dinámica del rio se encuentran equilibrados en éste punto. De este modo, y a pesar de su proximidad al lecho del rio, sólo las mayores "crecidas" favorecidas por la escorrentía superficial de las áreas anejas pudieron inundar el Monasterio de la Cartuja.

Palabras clave: Rio Guadalquivir, Inundaciones, Isla de la Cartuja.

1. Introduction

"Isla de la Cartuja" is located on the west bank of the Guadalquivir River, opposite the city of Seville, in the southwest of the Iberian Peninsula (Spain). It has an important social and cultural inheritance. Since the fourth century B.C., Isla de la Cartuja has been inhabited, with a long history of establishments and abandonments by several civilizations: Romans, Moslems and Christians. Archaeological remnants of these civilizations are vertically superposed, and are separated by clay sedimentary beds deposited from floods of the Guadalquivir River. Thus, for a long time, historians and archaeologists thought that these

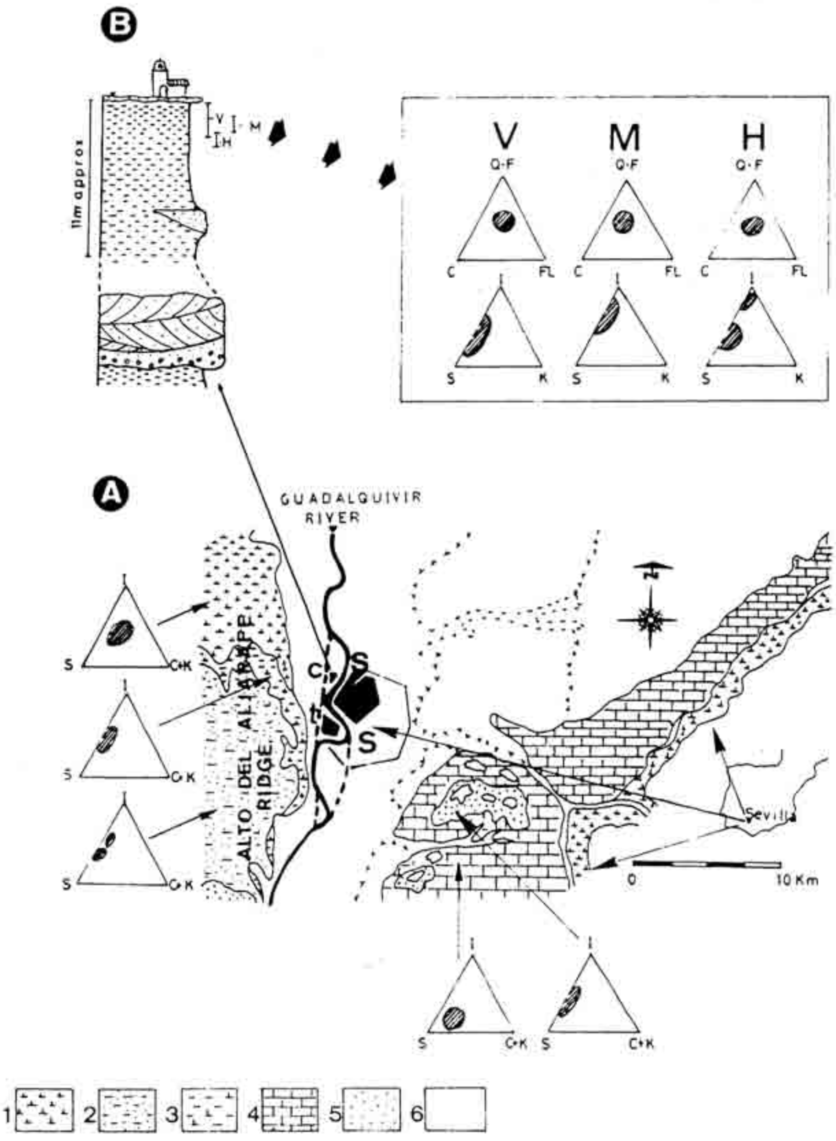

Figure 1.- (A) Geological sketch of Tertiary and Quaternary sediments outcroping around the Seville-Isla de la Cartuja area (modified from Galán and Pérez, 1989). Clay mineralogy is included in ternary diagrams. (B) Idealized estratigraphic log of Isla de la Cartuja alluvial floodplain including location and mineralogical composition of analysed samples. LEGEND: 1) Blue marls; 2) Sandy silts; 3) Silts and marls; 4) Calcareous sandstones; 5) Sands; 6) Undifferenciated Quaternary. TERNARY DIAGRAMS: Q-F) Quartz and feldspars; C) Carbonates; FL) Phyllosilicates; I) Illite; S) Smectites; C+K) Chlorite and Kaolinite; K) Kaolinite. POPULATIONS: S) Seville at present; s) Seville at fifteenth century; t) Triana; c)Isla de la Cartuja.

Figura 1.- (A) Esquema geológico de los sedimentos terciarios y cuaternarios del área Sevilla-Isla de la Cartuja (modificado de Galán y Pérez, 1989). Se incluyen diagramas ternarios de mineralógia de arcillas. (B) Columna estratigrádica idealizada de la llanura aluvial en la Isla de la Cartuja. LEYENDA: 1) Margas azules; 2) limos arenosos; 3) margas y limos; 4) Areniscas calcáreas; 5) Arenas; 6) Cuaternario indiferenciado. DIAGRAMAS TERNARIOS: Q-F) Cuarzo y feldespatos; C) Carbonatos; FL) Filosilicatos; I) Ilita; S) Esmectitas; C+K) Clorita y caolinita; K) Caolinita. POBLACIONES: S) Sevilla actual; s) Sevilla en el s. XV; t) Triana; c) Isla de la Cartuja.

floods played an important role, together with social aspects, in accounting for the frequent abandonment of the site (Escacena Carrasco, 1983; Amores, 1992).

This paper presents scientific support for new archaeological-historical hypotheses which refute the "natural catastrophe" factor as the main motive in the successive abandonments of Isla de la Cartuja.

The Santa María de las Cuevas Monastery (today named Cartuja Monastery) is the most conspicuous feature amongst all the archaeological wealth of Isla de la Cartuja. It is a building of the Carthusian Order, whose social influence and cultural activity had a crucial significance at the time of the discovery of the Americas. Accordingly, the Santa María de las Cuevas Monastery is considered to be the focal point of economic and cultural interchange during those times (fifteenth century).

The application of sedimentology to archaeological problems examines historical events from a scientific viewpoint and allows us a better understanding of the past.

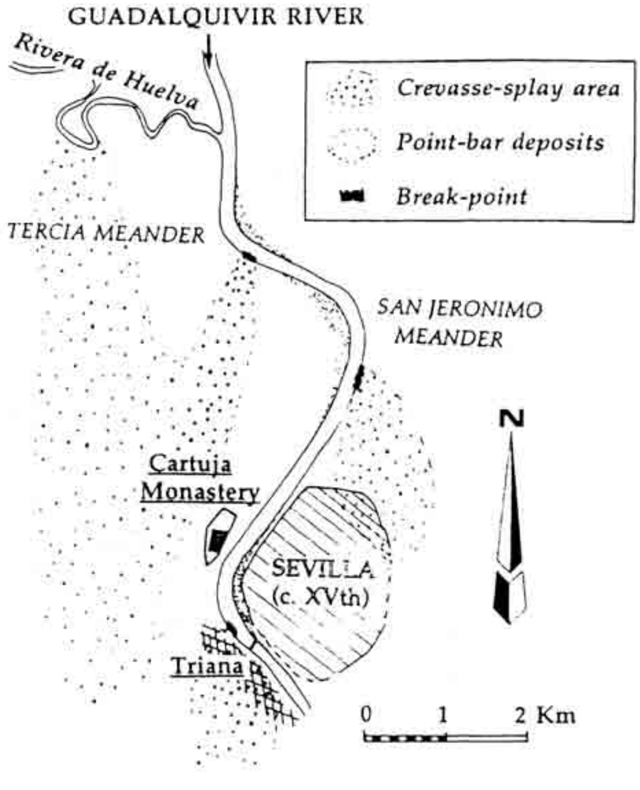

Figure 2.- Geographical and sedimentological sketch of the Cartuja-Seville-Triana area. Dotted zones were easily flooded.

Figura 2.- Esquema geográfico y sedimentológico del área de La Cartuja-Sevilla-Triana. La trama de puntos indica las zonas que eran facilmente inundables.

2. The Guadalquivir River

The Guadalquivir River flows to the WSW, subparallel to the Betic structural grain. Its drainage area is 46000 km^2 in size (Lautensach, 1967), with a variable discharge related to the seasonal character of river flow due to the local Mediterranean climate with a strong Atlantic influence (Alonso, 1989).

The sinuosity coefficient ranges from 1.3 in the upper reaches to 1.8 the lower part, where the Guadalquivir River can be considered as a meandering stream (after Miall, 1978; Rust, 1978; Schumm 1977/1981).

Two factors control the actual location of the Guadalquivir River and the cartographic distribution of its deposits:

- Uplift of Betic Belt, to the south.
- The topographic barrier formed by the southern margin of Hercynian Massif, to the north.

By mapping river deposits (Pérez Gonzalez *et al.*, 1989), we can deduce two wide stages in the evolution of the Guadalquivir River:

1) progradational stage (Lower-Middle Pleistocene): northern migration of the river with successive incision of the channel, which deposited wide terraces.

2) aggradational stage (Upper Pleistocene-Holocene). It represents firstly, the termination of channel migration and, secondly, stabilisation of the modern riverbed which has been scarcely modified since the Middle Pleistocene. A detailled analysis of this second stage was made by Baena Escuredo (1993).

In the lower part of the river, from Seville to the river mouth, fluvial dynamics are very different, with important morphological modifications (Menanteau, 1982) which are beyond the scope of this study.

3. Geological setting

The Guadalquivir valley coincides with the basin of the Betic orogenic foreland. Outcrop in the river basin includes a thin layer of Triassic rocks and a thick formation of Miocene blue clays and calcareous marine sandstones. The intervening Jurassic and Cretaceous do not crop out, except as allochthonous blocks within the Miocene sediments. Tertiary and Quaternary sediments outcrop around Seville and Isla de la Cartuja (figure 1).

- Tertiary sediments are mainly marls, silts and sands constituting the following lithological units: blue marls, silts and marls, sandy silts, calcareous sandstones, green marls, and basal sands.
- Most of the Quaternary sediments in the area are related to the evolution of the fluvial system.

Relative to the Guadalquivir channel system, the study area incorporates the transition from the middle (transportation) to lower (depositional) section. Isla de la Cartuja is within the alluvial floodplain of the river, on the convex bank of a meander encircling Seville (figure 1).

Morphologically, near Seville the Guadalquivir River valley is asymmetric because river migration to the NW eroded the west bank of the river and generated the present "Alto del Aljarafe" ridge (figure 1).

Table 1.- Granulometric analyses *(Análisis granulométricos)*

Sample	>420 u	420-100 u	100-63 u	<63 u
V-1	-	-	8.1	91.9
V-2	-	2.6	6.0	91.4
V-3	-	17.6	4.8	77.6
V-4	-	6.0	7.5	86.5
V-5	-	4.0	12.5	83.5
V-6	-	4.6	9.0	86.4
V-7	-	1.6	12.0	86.4
V-8	<0.1	5.3	9.8	84.9
V-9	0.8	10.5	13.7	75.8
V-10	-	-	14.0	86.0
V-11	1.5	4.0	10.4	85.6
M-1	-	0.8	8.9	90.3
M-2	-	0.8	5.0	94.2
M-3	-	8.0	10.4	81.6
M-4	-	-	5.7	94.3
H-1	15.3	19.0	6.0	59.7
H-2	-	5.3	5.3	89.4
H-3	-	36.0	6.8	57.2
H-4	13.4	20.0	4.6	62.4
H-5	23.0	16.0	6.7	54.3

4. Granulometric Data and Clay Mineralogy

Outcrops within the study area and mineralogic and granulometric analysis (tables 1 and 2) show a stratigraphically homogeneous unit which is constituted by fine-grained massive sediments, related to fluvial dynamics of the Guadalquivir River.

On account of building works associated with the "Universal Exposition of Seville (EXPO'92)", it has been possible to examine vertical sections (logs H, M and V in figure 1). These extended no more than 4 meters below ground level because, at this depth, a level with several ceramic kilns dating from Almohade times (XIII century) were encountered.

Table 2.- Mineralogic analyses. Column "CAR" includes calcite and dolomite contents (dolomite content is quite constant and represents 10-15% of the whole rock). *(Análisis mineralógico. La columna "CAR" incluye contenidos en calcita y dolomita (los contenidos en dolomita se mantienen constantes y representan 10-15% de la roca total).*

	Whole rock mineralogy				Clay mineralogy		
Sample	PHYL.	Q.	FD.	CARB.	IL.	KAOL.	SM.
V-1	25	35	5	35	40	10	50
V-2	25	30	10	35	30	-	70
V-3	20	30	5	45	55	15	30
V-4	35	30	5	30	35	15	50
V-5	35	25	10	30	50	10	40
V-6	30	30	5	35	25	10	65
V-7	35	30	10	25	55	15	30
V-8	30	40	5	25	35	-	65
V-9	40	30	5	25	35	5	60
V-10	35	30	5	30	-	-	100
V-11	35	35	5	25	25	-	75
M-1	25	35	5	35	15	-	85
M-2	25	35	5	35	25	15	60
M-3	20	40	5	35	30	5	65
M-4	25	35	5	35	25	-	75
H-1	40	25	5	30	40	-	60
H-2	35	30	5	30	35	10	55
H-3	35	25	10	30	100	-	-
H-4	30	25	10	35	35	-	65
H-5	40	25	10	25	85	-	15

These uppermost four meters consist of clays and silts, deposited during the 200 years between 1200 A.D. (end of Almohade time in the region), and 1400 A.D. (the time of Monastery construction). Mean rate of sedimentation is about 20 mm/year.

Granulometric analyses (table 1) show that grain size is generally less than 63 u. This fine grainsize and the absence of sedimentary structures indicate that sediments were deposited out of suspension, and exclude any other process of deposition (e.g. gravity flows).

Mineralogic analysis (table 2) has been carried out in two stages: a) by X-ray diffraction of whole-rock samples in order to determine the bulk mineralogy of the sediments and proportions of different mineral phases (phyllosilicates, quartz, feldspar and carbonates); and b) by X-ray diffraction of oriented clay particle aggregates, with semiquantitative modal determinations of illite, kaolinite, smectites and interstratified illite-smectite.

Whole-rock sample analyses show quite similar mineral patterns for different samples (table 2, figure 1). Clay minerals are mainly illite and smectite with kaolinite as an accesory (figure 1). Only illite shows a good crystallinity; on the contrary the crystallinity of smectites is low, so interstratified illite-smectite is included in table 2 as smectites.

Both whole-rock mineralogy and clay mineralogy are indistinguishable from Tertiary sediments outcropping near Seville (Galan & Perez, 1989) (figure 1). In relation to the textural and mineralogical characteristics of alluvial flood clays and active fluvial dynamics, there is no evidence of soil formation nor of diagenetic mineral growth. All this seems to indicate that the alluvial floodplain sediments are largely derived from erosion of these neighbouring sediments.

Mineralogical composition of alluvial flood clays of the Guadalquivir river indicates a very impermeable substratum. Measured coefficients of infiltration capacity are near nil (0.5 mm/ 13m).

5. Relationship between the fluvial dynamics of the Guadalquivir River and the history of Isla de la Cartuja

Floods are common events related to the fluvial dynamics of the Guadalquivir river. As Isla de la Cartuja is in an alluvial plain, historically it was frequently flooded (figure 2). Historical records (Vanney, 1972) show major river overflows that flooded Seville from the fifteenth century to today, with rises of more than 11 meters above the normal river level in Seville town (figure 3).

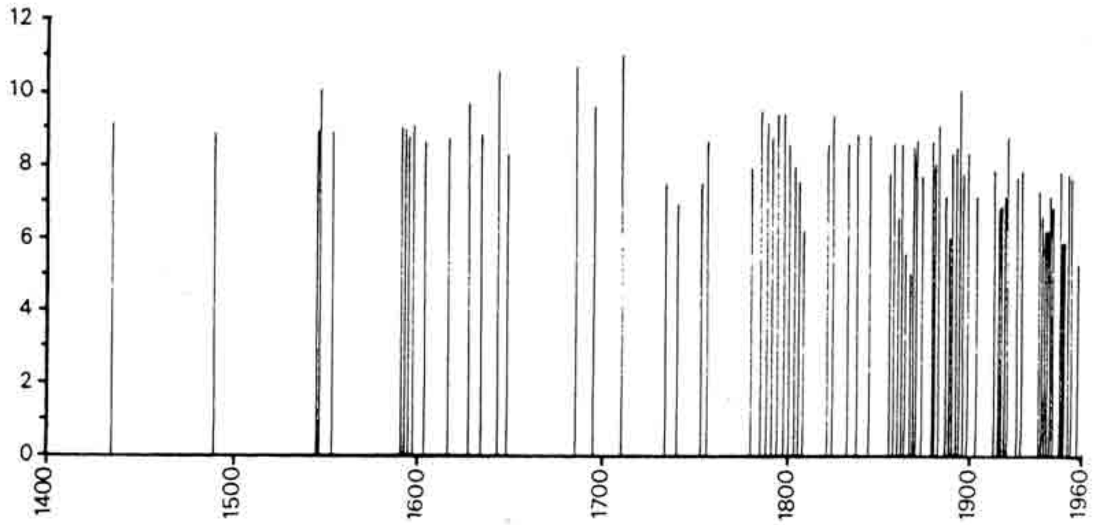

Figure 3.- Rises of level-water (in metres) during major overflows of the Guadalquivir River from fifteenth century to 1960 (modified from Vanney, 1972).
Diagrama que cuantifica (en metros) el ascenso del nivel del agua, durante las épocas de crecida, del rio Guadalquivir desde el siglo XV hasta 1960 (modificado de Vanney, 1972).

Construction of Santa María de las Cuevas Monastery (1404 A.D.) is an important datum in the study of the lateral migration of the Guadalquivir riverbed. Since construction of the monastery, the river has been channelized between Seville on the left bank and the monastery and Triana village on the righ bank (figures 1 and 2). This quasi-artificial style of channelization blocks lateral migration of the Guadalquivir riverbed , and enhances aggradation of fluvial deposition. The vertical stocking mades a dam effect which leads to the breaking of levees located downstream from the maximum curvature point of the Seville meander. Thus, areas located downstream from this point were flooded frequently. Nevertheless, they were never abandoned for their inhabitants.

From a town-planning viewpoint, Isla de la Cartuja is optimally located in relation to the nearby villages, despite its exposure to floods. It was only flooded during exceptionally high river levels. Figure 4 is an idealized sketch showing the level-river rises during a hypothetical flood, note that Triana would be flooded earlier than Monastery area.

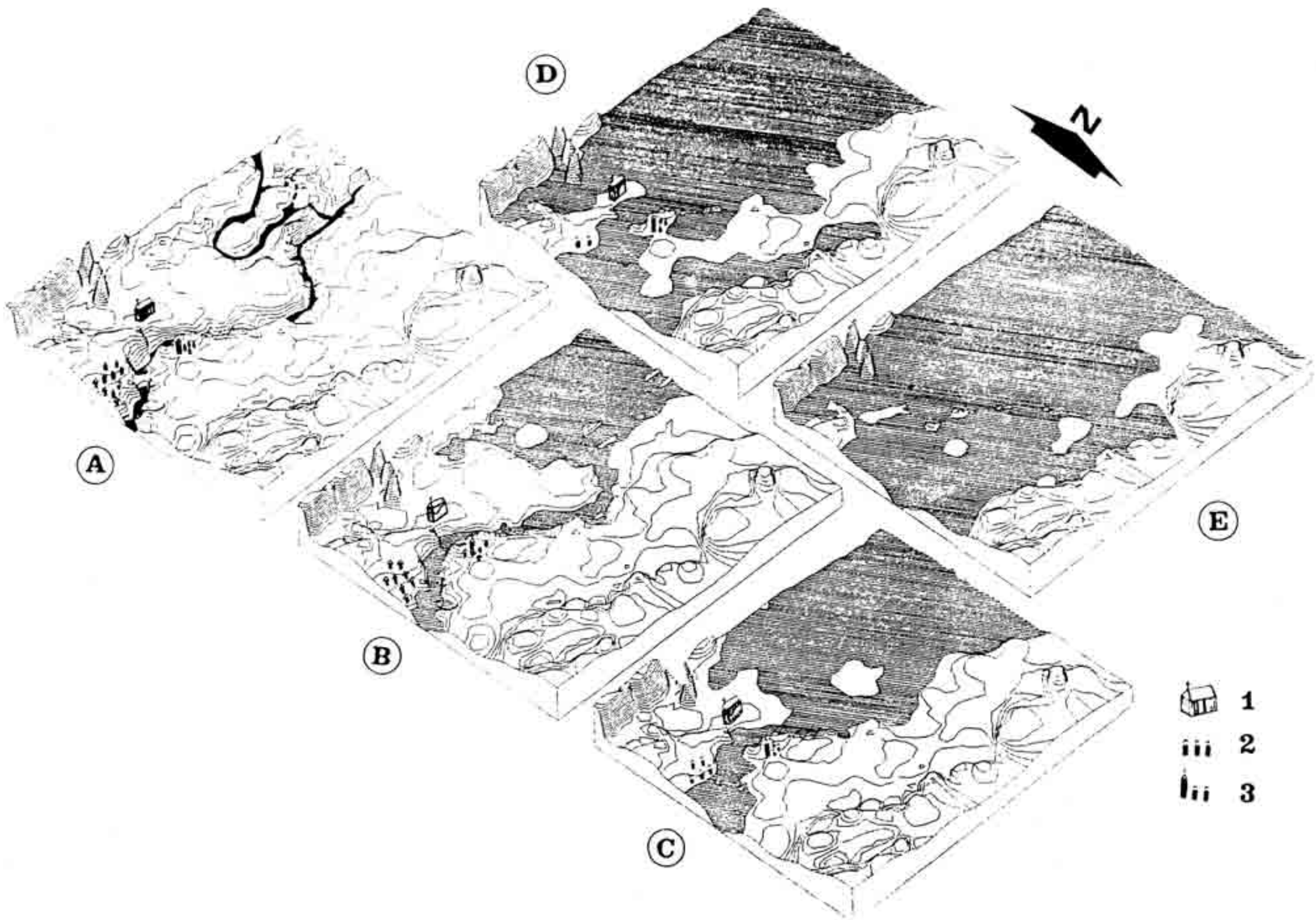

Figure 4.- Sketchs of the Seville-Triana-Isla de la Cartuja area (fifteenth century) showing some idealized vertical rises of Guadalquivir river water-level. Lined zones correspond with flooded areas. LEGENG: 1) Cartuja Monastery.; 2) Triana.; 3) Seville.; A) Normal water-level of the Guadalquivir River.; B) Water-level rise of 4 m; C) Rise of 6m; D) Rise of 7m; E) Rise of 8m.

Bloques diagrama que muestran el ascenso vertical del nivel del río en estados idealizados de crecida del río Guadalquivir en el área Sevilla-Triana-Isla de la Cartuja. El área rayada corresponde a la zona inundada. LEYENDA: 1) Monasterio de la Cartuja; 2) Triana; 3) Sevilla; A) Bloque diagrama con el nivel del río a su altura habitual; B) Idem con un ascenso del nivel del agua de 4 metros; C) 6 m de ascenso; D) 7 m de ascenso; E) 8 m de ascenso.

6. Conclusions

Modern evolution (Recent times) of the Guadalquivir River in the study area is charactericed by:

- A main vertical deposition of sediments related to the second aggradational stage.
- The stabilization of channel emplacement according to the ending of lateral migration process.
- The development of the alluvial plain whose sediments are the Cartuja Monastery substratum.
- The water that flooded the Monastery area was mainly runoff superficial water coming from the close uplands (Aljarafe ridge). Consecuently, the Aljarafe ridge is the main source of the alluvial plain sediments.

Although the Monastery was located in the alluvial plain of the Guadalquivir River, exactly on the convex side of the Seville meander, its location is stable in relation with the present river dynamic. The Monastery is located upstream of maximum curvature point of the Seville meander. So, the risk of flood was less in relation to other nearby places (e.g. Triana).

Only the biggest historical floods had an effect on the Monastery of Cartuja area which, in spite of its proximity to the channel, needed the devastating contributions from adjacent tributaries and of runoff water from nearby uplands (Aljarafe ridge) to flood the Monastery area.

Thus, successive inhabitants's establishments and abandonments of the Isla de Cartuja area were related only to social and socio/political factors, and were not dependent on river dynamics. Residents of Cartuja, Triana, Seville and other nearby areas, accustomed to these floods, evidently regarded them as a quasi-normal nuisance, since none of these settlements were abandoned as a result of floods.

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References

Alonso, J. (1989): Climas españoles. In V. BIELZA DE ORY (coordinador) *Territorio y sociedad en España VI*, Taurus. Madrid. 217-256.

Amores Carredano, F. (1992): Arqueología y Asentamientos: La Cartuja y su entorno. In: *Historia de la Cartuja de Sevilla, de ribera del Guadalquivir a recinto de la Exposición Universal.*. Turner. Sevilla. 31-48.

Baena Escudero, R. (1993): *Evolución Cuaternaria (3 m.a.) de la depresión del Medio-Bajo Guadalquivir y sus márgenes (Córdoba y Sevilla)*. Tesis Doct, Univ. Sevilla, 589 p.

Borja Barrera, F. (1992): *Cuaternario reciente, Holoceno y periodos históricos del SW de Andalucia.*. Tesis Doct, Univ. Sevilla. 462 p.

Escacena Carrasco, J.L. (1983): *Problemas en torno a los orígenes del urbanismo a orillas del Guadalquivir*. Ed. Gades. V.11. Cadiz. 39-83.

Galán, E. & Pérez, J. (1989): *Geología de Sevilla y alrededores. Características geotécnicas de los suelos del área urbana.* Ayuntamiento de Sevilla (ed). Sevilla. 255 p.

Lautensach, H. (1967): *Geografía de España y Portugal.* Vives. Barcelona. 799 p.

Menanteau, L. (1982): *Les Marismas du Guadalquivir, exemple de transformation d'un paysage alluvial au cours du Cuaternaire récent.* Doct. Thesis, Univ. Sorbona. París. 154 p.

Miall, A.D., ed. (1978): *Fluvial sedimentology*. Mem. Can. Soc. Petrol. Geol. nº 5. Calgary. 859 p.

Pérez González, A; Cabra Gil, P. & Martín Serrano, A. (Coord.) (1989): *Mapa del Cuaternario de España*. Escala 1:1.000.000. I.T.G.E., Madrid.

Rust, B.R. (1978): A classification of alluvial channel systems. In A.D. MIALL (ed): *Fluvial sedimentology*. Can. Soc. Petrol. Geol. nº 5. Calgary. 187-198.

Schumm, S.A. (1977): *The fluvial system.* Wiley and Sons. New York. 338 p.

Schumm, S.A. (1981): *Evolution and response of the fluvial system. Sedimentological implications.* S.E.P.M. Spec. Public. nº 31, Tulsa, 19-39.
Vanney, J.R. (1972): *L'Hidrologie du Bas Guadalquivir*. C.S.I.C., Madrid. 175 p.