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Morphology of Buried Valleys under a Holocene Alluvial Fan: Reconstruction Based on Geodatabase of the Arakawa, Central Japan

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Abstract

The analysis of newly provided geodatabase revealed three-dimensional architecture of buried valley filled with gravelly fluvial deposits under toe of the present Arakawa alluvial fan. Trace of the valleys indicated the confluence of two river systems, one of which is in the Arakawa system and the other in the Tonegawa one. Morphologic and stratigraphic characteristics as well as some age-control data illustrated the geomorphic development of the fan since the Last Glacial lowstand. The stages of valley development correspond with relative sea-level changes and associated geomorphic evolutions at downstream lowlands. The incision of valleys is considered the result of change in river regime which occurred in the earlier phase of the postglacial sea-level rise.

Key words: *borehole logs, GIS, Holocene, buried valleys, the Arakawa*

Introduction

In recent years, there are notable numbers of study on Latest Pleistocene to Holocene sediment. Case studies on densely age-determined sedimentary cores clarified strong control of relative sea-level change on fluvial − shallow marine sedimentary body (Masuda, 2007). At the same time, three-dimensional analyses of sedimentary body were performed based on geodatabase storing enormous borehole logs and actual architectures of sedimentary bodies were reconstructed (e.g., Yamaguchi et al., 2006; Eto et al., 2008). In the other hand, gravel dominant sediments are not covered by these studies and their behavior in last 10 ka is not fully investigated. This situation is aroused because gravel beds are not suitable for drilling core analysis and determining ages of sedimentation. In addition, there are few borehole logs penetrating gravel beds because most of borehole surveys are finished when drill reached gravel beds. However, it is important to

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understand behavior of gravel bed in last 10 ka in contexts of changes in relative sea-level, sediment discharge and water flow, so that comprehensive analysis of whole drainage system is needed to predict future geomorphologic change at densely populated alluvial plain.

We attempted to analyze gravel dominant alluvial plain located at uppermost part of Kanto Plain, central Japan. Here we show three-dimensional architectures of buried gravel beds reconstructed from geodatabase built of existing borehole logs. History of geomorphology and sedimentary body development since the Last Glacial are discussed and modeled based on the architecture and some age-control materials.

Alluvial fan and lowland of the Arakawa

The Arakawa (Ara river) forms alluvial fan and following alluvial lowland. So that there are some major cities, arterial roads and railways, this area is densely populated and plenty of borehole logs are available.

There are several river terraces developed by the Arakawa since the Late Pleistocene. The lowland is located on incised valley, which was past flow path of the Arakawa and the Tonegawa (Tone river) at the Last Glacial (e.g., Matsuda, 1974; Kikuchi, 1979). The Tonegawa changed its course and left the lowland around 3 ka (Eguchi and Murata, 1999).

An active reverse fault called Fukaya－Ayasegawa fault is striking northeast－southwest, displacing river terraces and sediments younger than the Middle Pleistocene (vertical displacement rate is estimated as 0.4 m/ky; Mizuno et al., 2004).

The stratigraphy of shallow subsurface geology (about 50 m depth) was investigated based on analysis of existing borehole logs. It is pointed out that gravel bed can be subdivided into two units based on result of N-value test (N-value represent hardness of soil), and that these gravel units represent valley like morphology (Furuta et al., 2009). This valley was traced for 6 km long, and the depth and width is reported to be 10 m and 100 －200 m, respectively (Furuta et al., 2009).

Developing and managing geodatabase

We collected more than three thousands of borehole logs from upper to middle part of the alluvial plain of Arakawa and Tonegawa (Fig. 1; Soutome et al.; 2004, Ogami et al., 2010). Most of the logs were obtained by geological surveys operated for public constructions and possessed by local governments.

Because the logs are not distributed equally, we built homogeneous dataset to reduce biases arise from unequal distribution. The dataset was built based on following rational. Methodology of Yamaguchi et al. (2006) was referred in the operation. We prepared square grids (1 km×1 km) over the study area and reviewed all the borehole logs inside each grid. Then we selected one or two logs among them according to core

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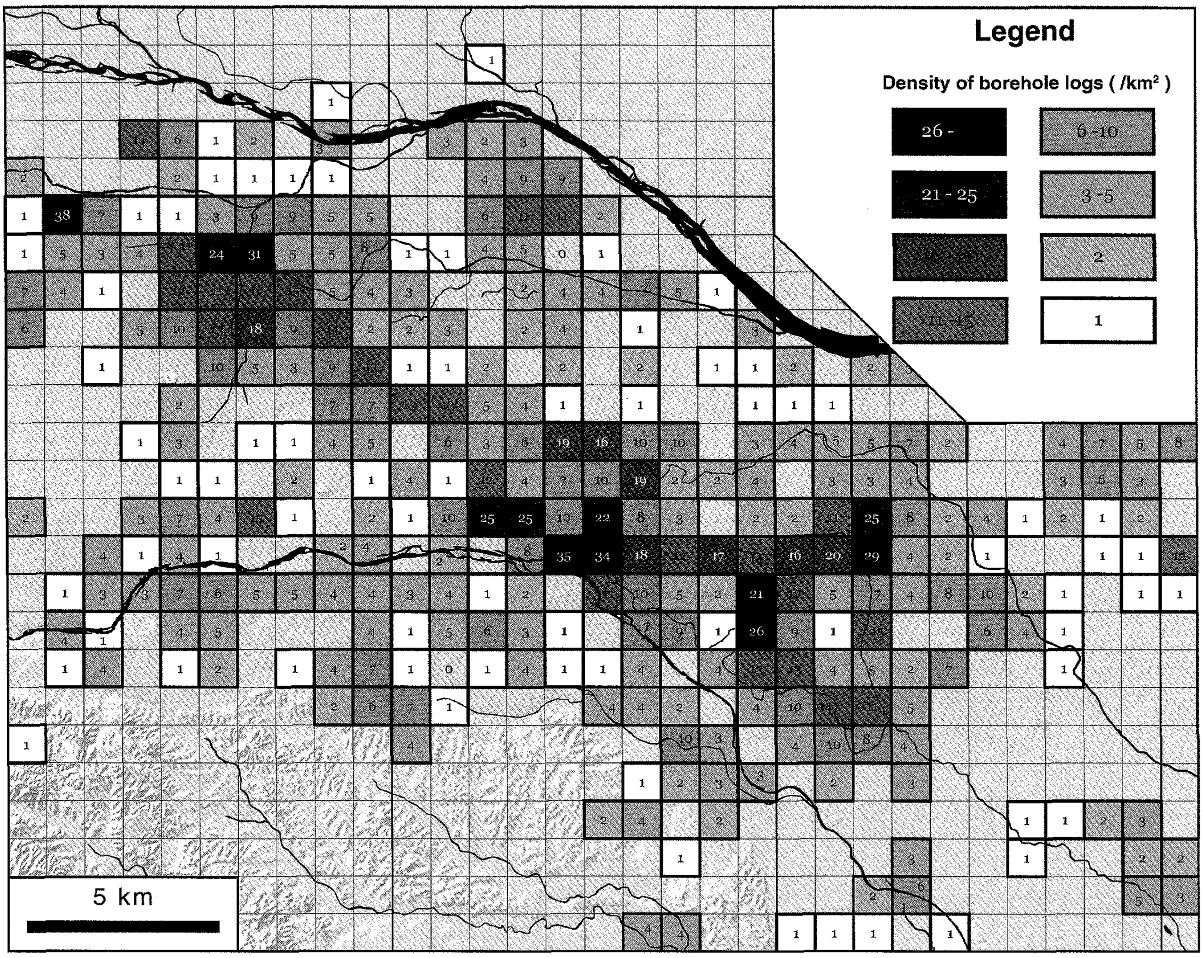

Fig. 1. Distribution of borehole logs. Squared mesh size is 1 km by 1km. Numbers inside each mesh represent density of borehole logs (/km^2). Extent is same as Fig. 3.

length, existence of detailed lithofacies description and N-value test operation for log selection. Selected logs were labeled and linked to each grid.

After the log selection, we reconstructed geological cross sections for every grid arrays of both north – south and east – west. We show typical cross sections in Fig. 2. Based on the cross sections, lithofacies description and N-value, subsurface sediments are classified into following units.

Unit I: Gravel bed with large N-value ($>$ 50). This unit mainly consists of cobbles and boulders with slight matrix. This unit accumulates tens of meters or forming valleys incising Pleistocene sandy or muddy sediments at upper and lower part of the basin, respectively.

Unit II: Gravel bed with small N-value (10–40). This unit mainly consists of pebbles and cobbles with much matrix. This unit is overlapping, incising or contemporaneous with unit I or III. Sediments of unit I are subdivided into two subunits according to their distribution. **Unit IIa**: distributed at valley like depression (P2, described in next chapter). **Unit IIb**: rest of unit II, overlapping unit I and unit IIa.

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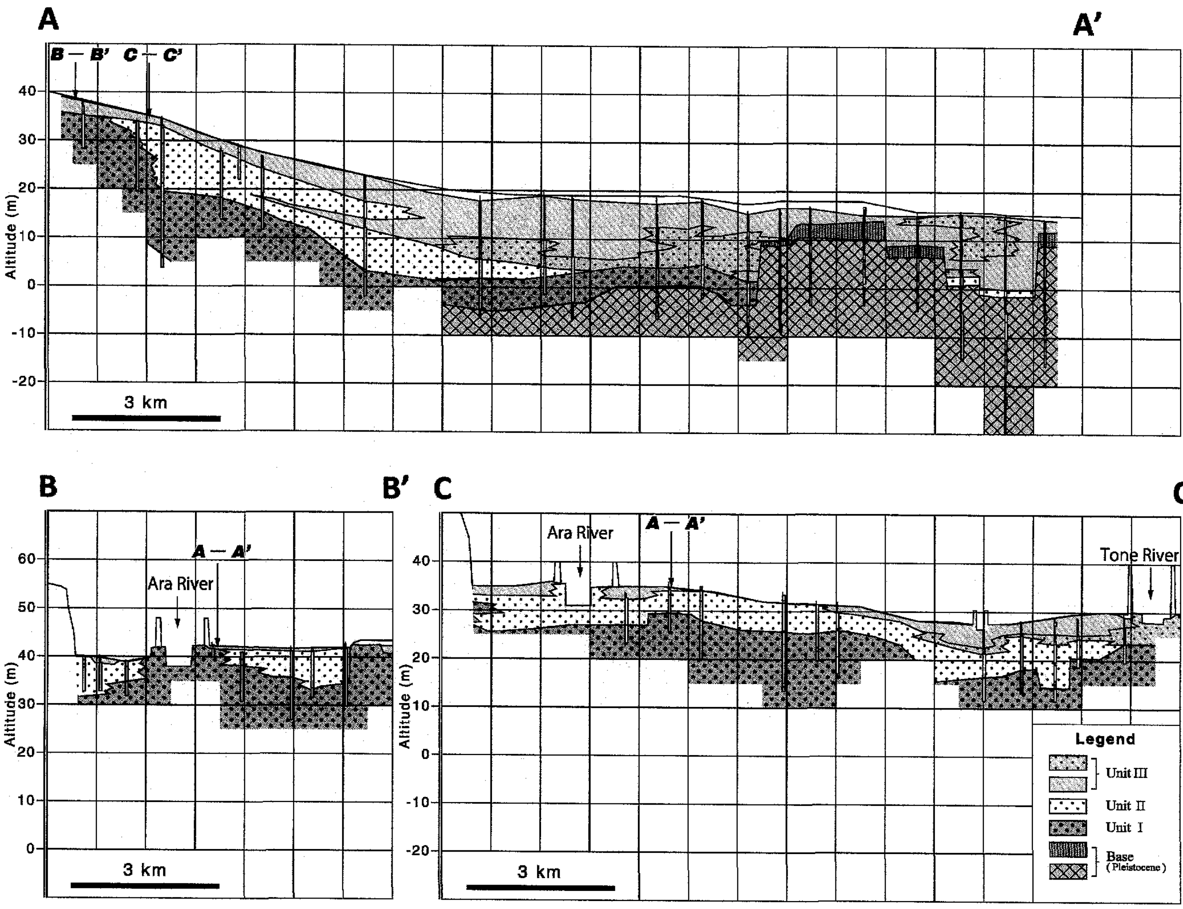

Fig. 2. Geological cross sections. Projection lines are shown in Fig. 3. A) Cross section of longitudinal plane of the Arakawa. Unit I/II boundary is clear between toe of present alluvial fan and flood plain. B & C) Cross sections of transverse plane of the Arakawa. At section B, structure that unit II aggradated on unit I is recognized. Unit I deposited near present course of the Arakawa is contemporaneous with unit II. At section C, valley like depression is observed near the Tonegawa.

Unit III: Muddy to sandy bed with small N-value (0–15). N-values of muddy beds are notably small (≒ 0). This unit includes peat layer.

Based on investigation of the geological cross sections, altitude of each unit boundary is determined and stored in the geodatabase. Form of each unit boundary is reconstructed using IDW interpolation based on the geodatabase. We operated these processes by using ArcGIS 9.3 (Esri, USA).

Three-dimensional architecture of buried valley

We reconstructed three-dimensional shape of unit I/II boundary (Fig.3). Relatively planar surface (P1) and valley like continuous depression (P2) are recognized. P1 and floor of P2 consist of unit I. P2 depression is filled with unit II. Altitude of P2 surface is descending unidirectional and paths of P2 are branched at upstream and joining at

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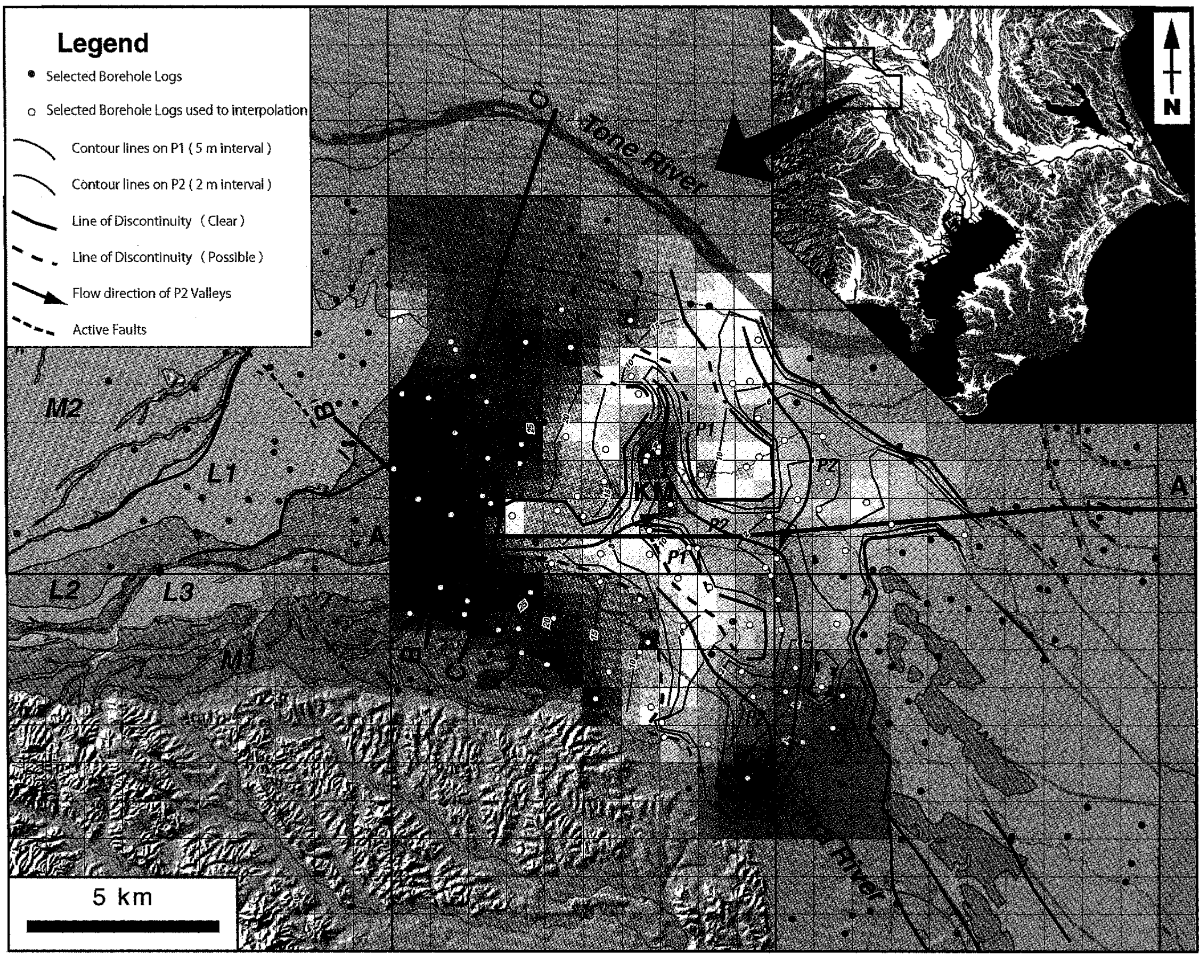

Fig. 3. Reconstructed morphology of buried alluvial plain and incised valley on the plain. Relatively planar surface (P1) and valley like continuous depression (P2) are recognized. They are bounded by solid and dashed line, which represent discontinuity of surface. The P2 valley is branched and joining at downstream. Flow directions of P2 valleys are roughly classified southward and eastward, and these valleys may have belonged to the Tonegawa system and the Arakawa system, respectively. The altitude of P2 surface is below −4 m asl. FK and KM are borehole locations where age control material was obtained (FK: Fukiage, KM: Kamino). Colored areas with letters (M1, M2 L1, L2 and L3) are Pleistocene fluvial terraces. Bold lines (A-A', B-B' and C-C') represent projection line of cross section in Fig. 2.

downstream. Such features of P2 morphology support the idea that P2 is river valley incising P1. In the other hand, P1 surface is correlated to surface of buried alluvial fan.

Descending directions of P2 are southward and eastward, suggesting these valleys belong to the Tonegawa and the Arakawa system, respectively. Depths of P2 valleys are 5–10 m and decreasing downstream. The surface of P2 and P1 are getting closer and crossing at downstream.

The brunched P2 valleys have at least three confluences. This area located at the merging point of Arakawa and Tonegawa when P2 valleys were active. The basin is narrowed downstream because Tertiary hills and Pleistocene terraces bound it.

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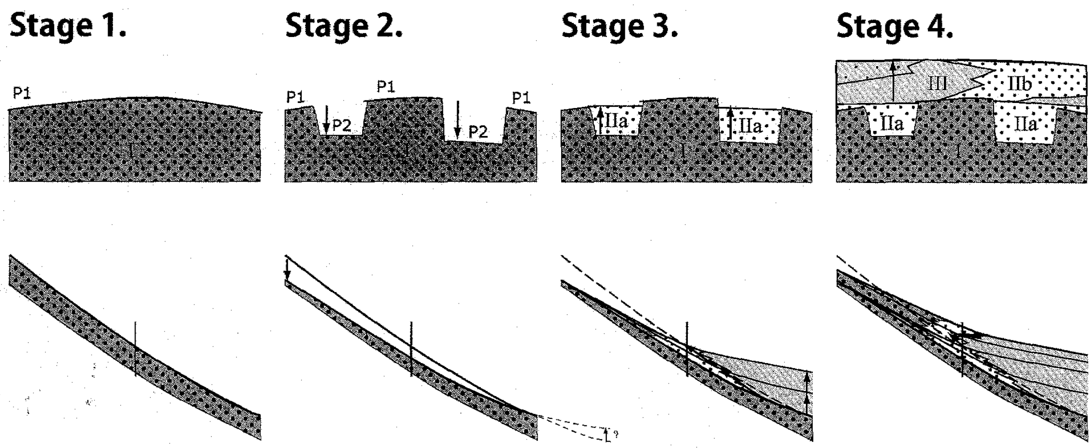

Fig. 4. Schematic Model of development of buried alluvial fan and incised valley. Characters of I, IIa, IIb and III represent unit classification. Upper and lower figures are cross and strike sections, respectively. The position of cross sections is indicated as vertical solid line in strike sections. Upward and downward arrows represent denudation and aggradation, respectively. See text for details.

Development of buried alluvial fan and incision of valley

The morphology of P1 and P2, characteristics of sediments, and some age-control materials illustrate following history of geomorphologic development (Fig. 4).

Stage 1: Sloped plane of P1 is formed. The both of Arakawa and Tonegawa flowed as braided river system and formed alluvial fan (P1). The fan consists of unit I gravel bed of 5–10 m thick. Therefore the lowest altitude of unit I base is below present sea-level, P1 plain was formed during lowstand of the Last Glacial. In this stage, unit I may transit to unit II in downstream.

Stage 2: P2 valleys incised P1 plain. The valleys belonged to the Arakawa system and the Tonegawa system and flowed into present course of the Arakawa. The altitude of P2 surface reaches lower than present sea-level, so that P2 valley was formed during lowstand. The fact that surface of P2 and P1 get closer as down the stream indicates that the slope of P2 valley was low-angled than that of P1 plain. Such shape of P2 valley could be formed as a result of down cutting of valley in upstream and aggradations in downstream. Aggradation in downstream suggests that this period was in transgressive stage after sea-level reached minimum in the Last Glacial Maximum. At the same time, down cutting of valley in upstream suggest that dynamic equilibrium of braded river system was disturbed by increase of traction power or decrease of sediment supply.

Stage 3: P2 valleys were filled with fluvial sediments. Unit IIa, the main component of valley fill, is composed of smaller grains than that of unit I. Decrease in grain size suggests landward migration of sedimentary system, which is common feature in transgressive stage. Radiocarbon dates obtained from bottom of unit III (directly covering unit I) at FK and boundary of unit IIa and IIb at KM are 8,640−8,990 cal yr BP

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(7,950±50 yr BP) and 6,603−6,741 cal yr BP (5,845±30 yr BP), respectively (Mizuno et al., 2004; Furuta et al., 2009). The former age is interpreted as beginning of P2 valley fill at FK site and the latter is interpreted as finishing of valley fill at KM site. These ages shows that P2 valley fill proceeded during postglacial sea-level rise.

Stage 4: Accumulation of finer fluvial sediments proceeds after fulfilled P2 valleys. This stage may have started soon after complement of P2 valley fill at KM site. Gravel bed (unit IIb) is migrating landward, indicating landward migration of sedimentary system including alluvial fan.

Conclusion and remarks

We revealed three-dimensional architecture of buried morphology accountable for in terms of changes in relative sea-level and river regime during postglacial. Systematically operated analysis worked to excavate such morphology even though formed and filled with gravel rich sediments. In this case study, contrast of N-value enabled to distinguish loose valley fill gravel from tight gravel that composes valley morphology. Accumulating case study at other gravel-dominated plain is requested to verify applicability of this methodology.

Detailed investigation based on actual date is requested to validate geomorphologic evolution history and is necessary to investigate linkage with changes of both upper and lower reaches.

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