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Gamma Log Trend Facies in the Choshui Fan-delta, Taiwan

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ABSTRACT

Between 1992 and 1997, under a project conducted by the Water Resources Bureau, more than 200 well loggings were measured by Taiwan Sugar Corporation Groundwater Center (TSCGC) in the Choshui and Pingtung areas. The purpose of this paper is to evaluate the workability of the log trend method in this hydrogeology investigation project. Previous studies used the Schlumberger formula to calculate the mud content and had a 40% error rate. The reason for this high bias is that mineral assemblage, casing, caves and borehole diameter variations shift the natural gamma readings. In the author's experience, borehole diameter variation is the major factor. The gradual shifting greatly reduces the exactness of the Schlumberger formula but isn't a serious problem when using the curve type method. In this research gamma logs in three boreholes of the Choshui fan-delta, Taiwan, are classified to basic log trend facies and compared with the core samples.

This study finds eight basic gamma log trend facies and these facies correspond very closely to the mud content or mud thickness. This research suggests that gamma log trends facies are useful to lithology interpretation of TSCGC's data and are valuable for further research into sedimentary environment reconstruction and aquifer geometry prediction.

(Key words: Well logging, Gamma log trend, Choshui fan-delta, Hydrogeology)

1. INTRODUCTION

Open hole natural gamma logging has been widely applied to calculate shale content for many years (Schlumberger, 1974). In groundwater investigation, the gamma log is used for calculating the mud content. However, previous studies have shown that four out of ten samples had an error in mud content greater than 10%, and have argued that the Schlumberger formula gives the correct rate in only 60% of cases (Table 1; Yuan *et al.*, 1994; Chen, 1997). Serious inaccuracy in using the Schlumberger formula was also found in the Taiwan Sugar Corpora-

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Table 1. Mud content from sieve analysis and gamma log.

No.	Sample depth(m)	Vmud *note 1	(Vmud)GR *note 2	Error(%)	Remark
1	23.0	13.66	14.10	0.4	
2	38.9	83.50	63.50	20.0	*
3	73.4	63.24	61.80	1.4	
4	83.2	12.02	15.30	3.3	
5	99.1	79.62	63.00	16.6	*
6	110.9	58.61	51.70	6.9	
7	130.1	3.84	1.70	2.1	
8	152.3	90.68	62.50	28.2	*
9	175.4	13.09	14.20	1.1	
10	191.3	71.98	33.50	38.5	*

Note:
1. Sieve analysis data from Yuan *et al.*(1994).
2. Calculated mud content by natural gamma from Chen(1997).
3. A mud content error rate larger than 10% will cause misinterpretation.
4. Core samples from Hou-An Well, Yuenlien.

tion Groundwater Center's log data (TSCGC, 1992-1997). In an aquifer, a 10% increase in mud will cause plugging of the porosity in the gravel and sand layer, and it will behave as an aquitard.

Between 1992 and 1997, under a project conducted by the Water Resources Bureau, more than 200 well loggings were measured by TSCGC in the Choshui and Pingtung areas. In the author's experience, borehole diameter variation is the major factor that may shift the natural gamma readings, with minor factors being mineral assemblage, casing, and caves (Figure 1, Table 2). For the purpose of monitoring two aquifer layers, the borehole diameter is usually 40 to 80cm and is bigger in the upper layer than the lower layer. The probe usually goes down and up along the centerline of the well to avoid unconsolidated layers collapsing. Natural gamma readings increase with depth into the hole as the borehole diameter decreases because as the probe nears the wall of borehole, it receives more gamma rays. Figure 1 shows the trend of a gradual increase in gamma rays with decreasing borehole diameter. The gradual shift greatly reduces the exactness when using the Schlumberger formula but is not a serious problem by curve type method.

A number of authors have reported that log trends respond well to lithology (*e.g.*, Pirson, 1977; Serra, 1985; Rider, 1986; Milton and Emery, 1996). The use of log trends in lithology interpretation has received much attention in recent years in Taiwan (Lee, 1992; Yu, 1997). However, no studies have investigated gamma log trends in groundwater wells. Usually, groundwater wells are bigger than petroleum wells in diameter and are composed of unconsolidated

Quaternary sediments. In groundwater monitoring of Water Resources Bureau wells, logs of conical wells were taken and the diameter effects should be considered as stated in the preceding paragraphs. This paper applies log trend method and presents the facies of gamma log trends from three groundwater boreholes in the Choshui fan-delta, Taiwan (Figure 2). All of the facies are compared with core samples in order to evaluate the workability of the method in subsurface hydrogeology investigation.

2. GEOLOGY SETTING

The wells under study are located in the Choshui fan-delta, central Taiwan (Figure 2). The wells are hydrogeological investigation wells of Taiwan Groundwater Monitoring Network Project. The cores of the wells are about 330m. The Ho-Shing well is in the middle of the fan-delta, the Hai-Yuan well is on the tidal flat of the lower fan-delta, and the Ton-Shin well is on the boundary.

The Choshui fan-delta is 60km wide and 40km long. Its apex is in Chukuo, and the morphology is a westward fan from 100m to the Taiwan Strait. The subsurface geology is composed of gravel in east with a transition to sand and mud in west (Figure 3). The deposition age of the upper 0-60m is Holocene and 60-330m is late Pleistocene (CGS,1995).

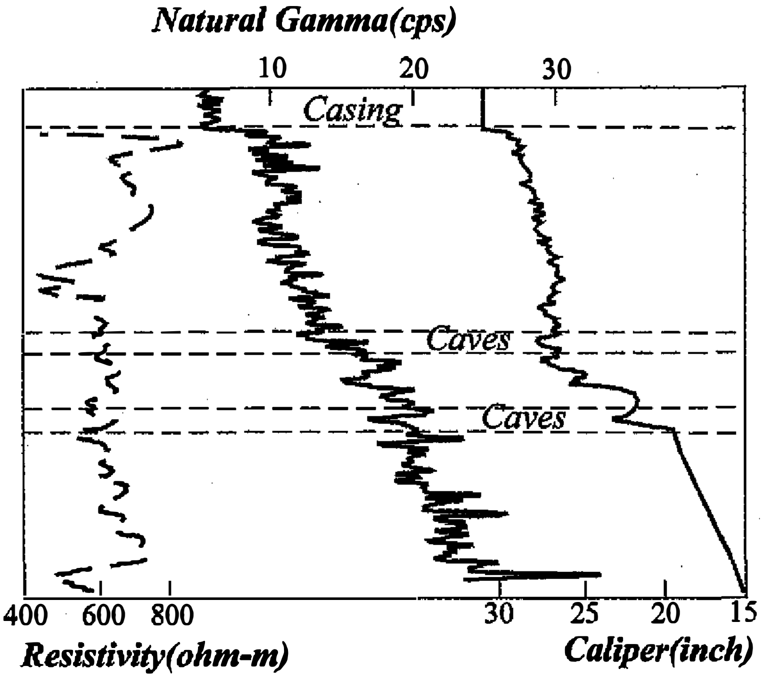

Fig. 1. Casing, caves and borehole diameter variations will shift natural gamma readings. Natural gamma reading increases down hole when borehole diameter decreases, and decreases when borehole has casing or caves.

Table 2. Borehole conditions.

Well name	Diameter and depth	Casing	E.C. of Drilling water
Ho-Shing	46cm(0-20m), 30cm(20-330m)	0-5m	1300
Hai-Yuan	40cm(0-180m), 35cm(180-280m)	0-3m	11000
Ton-Shin	30cm(0-300m)	0-45m	43000

*E.C.= Electrical Conductivity (uS/cm)

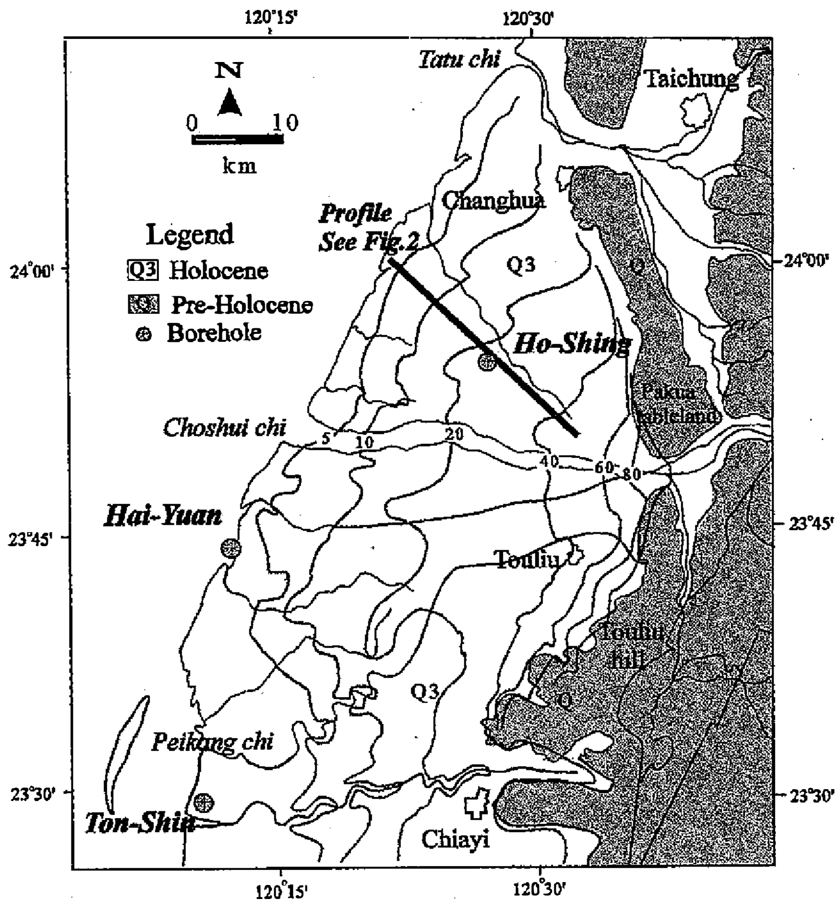

Fig. 2. Locality of boreholes and geology of study area (geology from Ho, 1986).

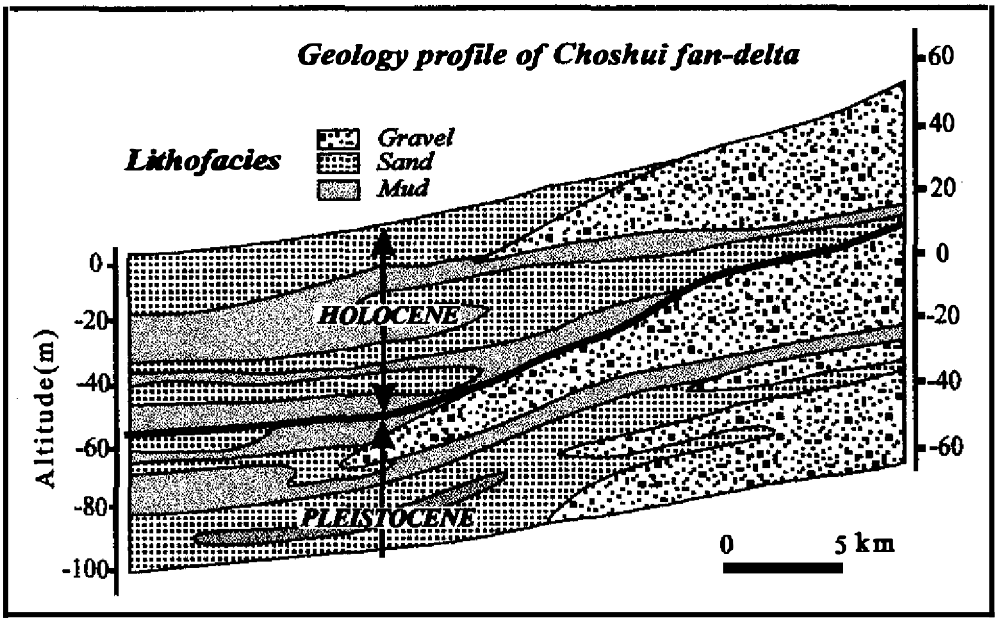

Fig. 3. Geology profile of Choshui fan-delta (lithology data from CGS, 1995).

3. LOGGING PROCEDURE

The logging system, "Geologer 3030" model by OYO Corporation, Japan, includes a combination probe, a battery, a set of sheaves, a winch, and a measuring recorder. The logging system measures resistivity, spontaneous potential and natural gamma. The probe descends the hole centrally with a velocity of about 5 m/min and takes one reading every 10cm. Because the drilling mud will emit some gamma rays, a mud scow must be used to clean the drilling mud from the hole before the measurements are taken. Well logging was undertaken after core boring and before construction of the casing and screen.

4. GAMMA LOG TRENDS

Gamma logs and lithology columns of the study wells are shown in Figure 4. Gamma logs are classified into eight basic log trends. Figure 5 shows centimeter by centimeter correlation of the lithology and log of the Ho-Shing well. The relation indicates that the gamma reading increases with increases in the mud layer thickness.

The eight basic log trend facies correspond to mud content or mud layer thickness (Figure 6). The contact relationship is gradual or sharp. (1) DU facies is where gamma ray gradually increasing upward, for example with mud content or thickness of mud layer increase upward and sand content or thickness of sand layer decreasing upward. (2) CU facies is where gamma ray gradually decreases upward, for example with mud content or thickness of mud layer decreasing upward and sand content or thickness of sand layer increasing upward. (3) IR facies is where gamma log curve fluctuates, for example with sand and mud interlayer. (4) BW facies is where gamma ray gradual decreases upward and then gradual increases upward, for example with mud content or thickness decreasing upward and then increasing upward. (5) LB facies is low gamma reading, sharp boundaries and no internal change, for example with massive sand layer. (6) RB facies is high gamma reading, sharp boundaries and no internal change, for example with massive silt or clay layer. (7) RP facies is low gamma reading but includes one or more sharp boundary thin high gamma layer, for example with the massive sand with thin mud layer. (8) LP facies is high gamma reading but includes one or more sharp boundary thin low gamma layer, for example with the massive mud with thin sand layer.

Basic log trend facies will mix as a superposition curve. For example, the layer between 10 and 30 meters in depth of Ton-Shin well shows a fluctuating IR curve but the gamma

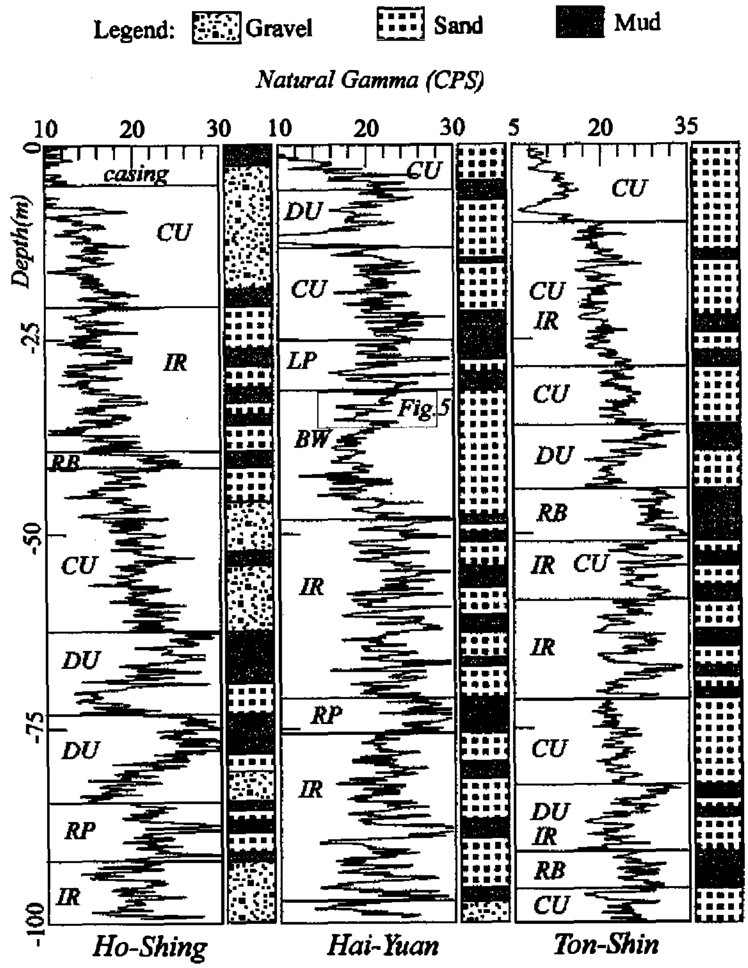

Fig. 4. Natural gamma logs, lithology, and interpretative log trend facies.

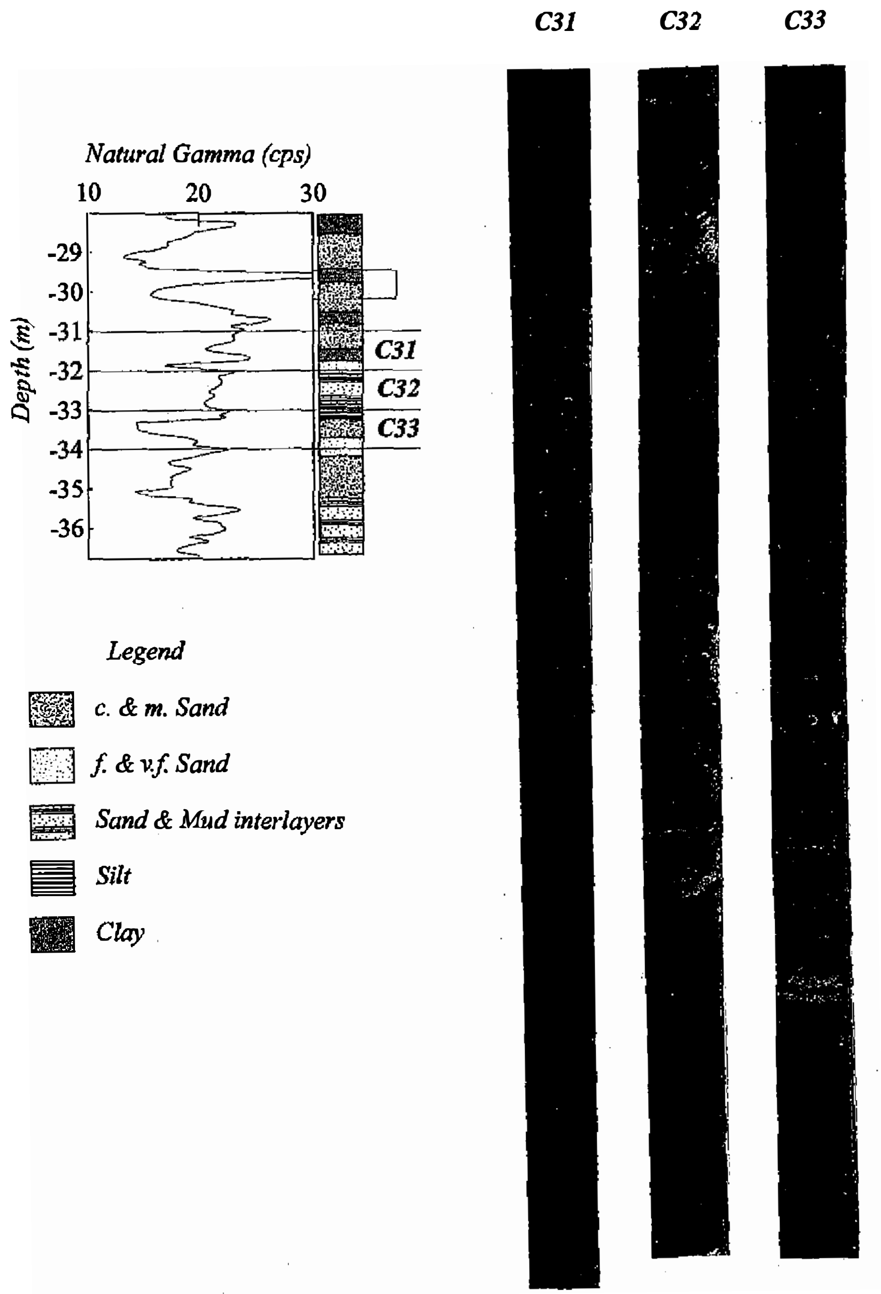

Fig. 5. Correlation between gamma log and cores. See Figure 4 also. Gamma log shows dirty upward sequence with reading from 15 cps (count per second) to 25 cps. Lithology of core shows that thickness of mud layer is increasing.

reading is also decreasing upward and shows as CU facies (Figure 4). The lithology of this layer is an interlayer of sand and mud, while the mud content and mud thickness is decreasing upward.

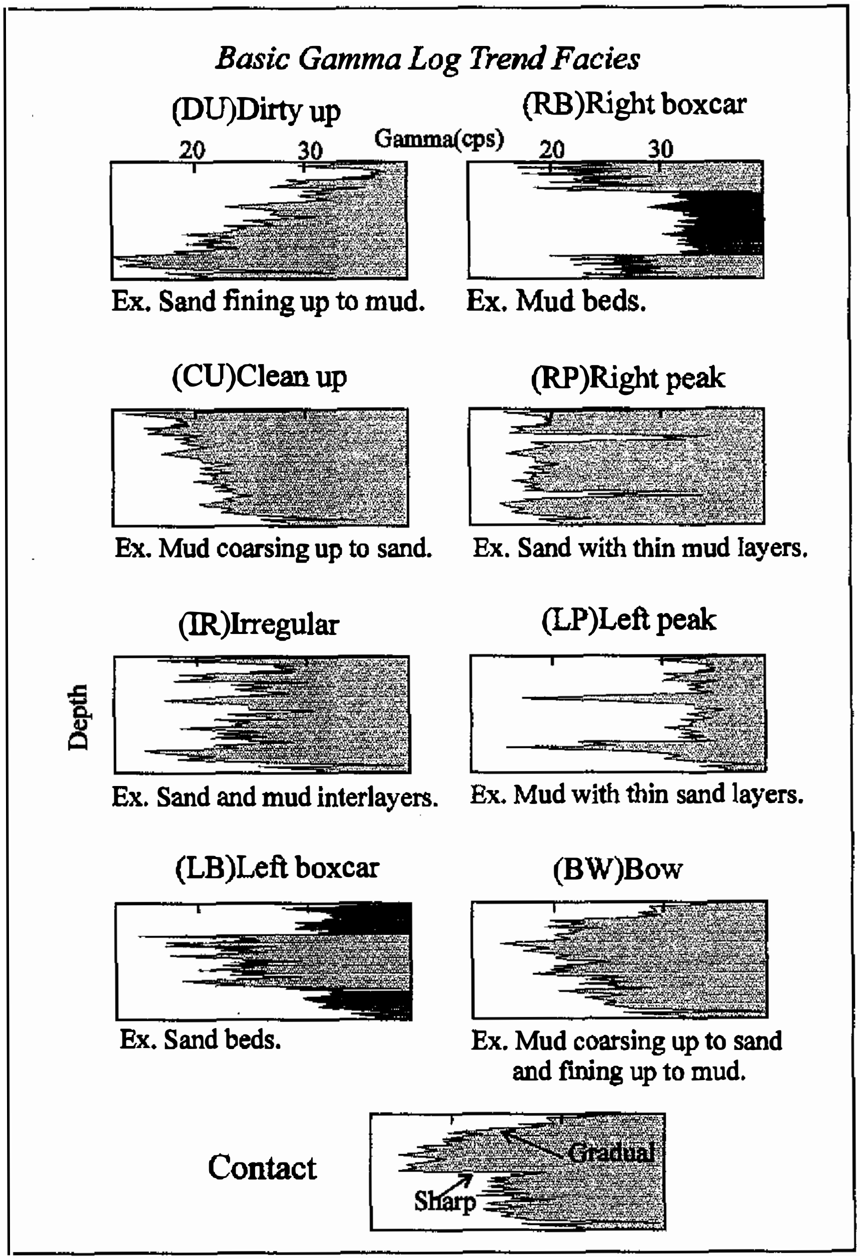

Fig. 6. Basic gamma log trend facies and contact.

5. DISCUSSION

Table 3 shows eight types of basic gamma log trends and the terminology used in previous studies and by the author. The facies BX, CU, DU, BW and IR follow the terminology used by Milton and Emery (1996). However, BX is divided into two facies, and each is composed of homogeneous sand (RB) and mud (LB), which are usually with a thickness of more than 5m. The LP and RP facies are defined by this study. For example, in the Hai-Yuan well, at a depth of 25-35m, LP facies is massive mud containing a thin sand layer. The two facies can also be found in Ho-Shing well, 85-93m; and in Hai-Yuan well, 71-76m. It is reasonable to include the two facies in basic gamma log trend facies.

Table 3. Terminology used in previous studies and this paper.

Gamma Log trend	Milton and Emery (1996)	Yu (1997)	This paper
Gradual upward decrease	Cleaning-up	Funnel	Clean up (CU)
Gradual upward increase	Dirtying-up	Bell	Dirty up (DU)
Low gamma, sharp boundaries, no internal change	Boxcar	Thin-cylinder	Left boxcar (LB)
High gamma, sharp boundaries, no internal change	-----	Thick-cylinder	Right boxcar (RB)
Gradual decrease then increase	Bow	-----	Bow (BW)
Fluctuation	Irregular	-----	Irregular (IR)
Low gamma, includes one or more sharp contact thin high gamma layer	-----	------	Right peak (RP)
High gamma, includes one or more sharp contact thin low gamma layer	-----	-----	Left peak (LP)

6. CONCLUSION

This paper presents three gamma logs and lithology for Ho-Shing, Hai-Yuan, and Ton-Shin wells in the Choshui fan-delta, Taiwan. The author used log trend method to classify the natural gamma logs and compared then with core samples for confidence. Eight basic facies were found in the three logs. Facies DU, CU, IR, BW, LB, and RB are quoted from Milton and Emery (1996), and facies LB and RB are defined by this paper. The log trend was correspond closely to mud content or thickness.

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REFERENCES

Central Geological Survey (CGS), 1995: Hydrogeology report of Choshui alluvial fan. Taipei, 102pp.

Chen, W., 1997: Hydrogeology of Taishi and Mialio. M.S. Thesis, Inst. Geol. Nat'l Taiwan Univ., Taipei, Taiwan, 66pp.

Ho, C. S., 1986: Geologic map of Taiwan. Central Geological Survey, MOEA, Taipei.

Lee, C. C., 1992: Apply well logging in reservoir exploration. unpublished report, CPC file, 141pp.

Milton, N. J., and D. Emery, 1996: Outcrop and well data. In: D. Emery and K. Myers (Eds.), Sequence Stratigraphy, Blackwell Science, 61-79.

Pirson, S. J., 1977: Geological well analysis. Gulf Publishing, Houston.

Rider, M., 1986: The geological interpretation of well logs. Blackie, London.

Schlumberger, 1974: Log interpretation manual/application, vol. II. Houston, Schlumberger Well Services, Inc.

Serra, O., 1985: Sedimentary environments from wireline logs. Schlumberger.

Taiwan Sugar Corporation Groundwater Center (TSCGC), 1992-1997: Report of groundwater monitoring well construction and tests. Hsin Ying, Taiwan.

Yu, L. F., 1997: Sequence stratigraphy of Mushan Formation. M.Sc. Thesis, Inst. Geol. Nat'l Taiwan Univ., Taipei, Taiwan, 125pp.

Yuan, P. D., L. S. Teng, and S. B. Lin, 1994: Sediments characteristics and distributions, Hydrogeology investigation of Choshui alluvial fan. Report of Central Geological Survey, Taipei, Taiwan.