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Hummel array and its comparison with schlumberger array in the south GORGAN – IRAN

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ABSTRACT: Hummel array measurements can be used to obtain the maximum information about distribution of resistivities in the earth and inhomogeneous that indicated from lateral . this array be used more in areas that because existence of difficults can't be used from schlumberger array . the resistivity data from such measurements can be interpreted as normal sounding schlumberger curves.
In this paper are compared geometric array factor , resistivity , depth of investigation and limiting depth of detection in hummel and schlumberger arrays.
The examples chosen from field tests in south GORGAN area show that with good rms (root means square) be interpreted resistivity data from hummel array with normal sounding schlumberger curves.

***Keywords*:** Hummel array , schlumberger array , resistivity, depth of investigation , limiting depth of detection.

INTRODUCTION

Consider hummel array measurements using one three electrode array with one current electrode at infinity (Figure 1).

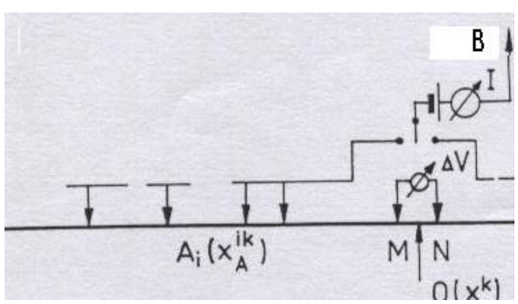

Figure 1. Hummel array

The current electrode Ai is located from one direction fixed center of potential MN the separation of the electrodes from center O is ri = Ai O .

The values of ri are chosen according to the maximum required investigation depth d so that maximum of ri >2d and distance of OB ≥ OA .

It will be shown that resistivity data from such array can be processed and presented in various ways to emphasize the different survey objectives , bed rock , topography , counductive or resistive dykes , contacts between rock formations with different resistivities.

Comparison between geometric array factors schlumberger and hummel arrays

Geometric array factor determined by :

$$k = \frac{2\pi}{[(\frac{1}{r_1} - \frac{1}{r_2}) - (\frac{1}{r_3} - \frac{1}{r_4})} \quad (1)$$

In hummel array current electrod B is infinity , thus we have:

$$\begin{cases} V_{Am} = \frac{\rho I}{2\pi} \frac{1}{r_i - a/2} \\ V_{AN} = \frac{\rho I}{2\pi} \frac{1}{r_i + a/2} \end{cases} \Rightarrow \Delta V = \frac{\rho I}{2\pi} (\frac{1}{r_i - a/2} - \frac{1}{r_i + a/2}) \quad (2)$$

$$\Delta V = \frac{\rho I}{2\pi} [\frac{(r_i + a/2) - (r_i - a/2)}{(r_i - a/2)(r_i - a/2)}] \Rightarrow \Delta V = \frac{\rho I}{2\pi} [\frac{a}{(r_i + a/2)(r_i - a/2)}]$$

$$\rho = \frac{2\pi \Delta V}{I} [\frac{(r_i + a/2) \times (r_i - a/2)}{a}] \Rightarrow k = \frac{2\pi (r_i + a/2) \times (r_i - a/2)}{a} \quad (3)$$

In schlumberge array , we have:

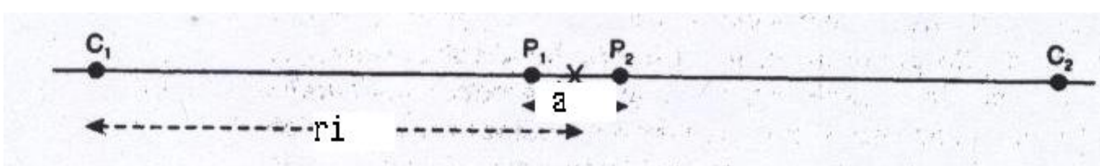

Figure 2 . schlumberger array

$$\begin{cases} r_1 = r_i - a/2 \\ r_2 = r_i + a/2 \\ r_3 = r_i + a/2 \\ r_4 = r_i - a/2 \end{cases} \quad (4)$$

$$k = \frac{2\pi}{(\frac{1}{r_1} - \frac{1}{r_2}) - (\frac{1}{r_3} - \frac{1}{r_4})}$$

$$k = \frac{2\pi}{(\frac{1}{r_i - a/2} - \frac{1}{r_i + a/2}) - (\frac{1}{r_i + a/2} - \frac{1}{r_i - a/2})}$$

$$k = \frac{2\pi}{2\left(\frac{1}{r_i - a/2} - \frac{1}{r_i + a/2}\right)} = \frac{\pi(r_i + a/2)(r_i - a/2)}{a} \quad (5)$$

Thus we can write :

$$K_{HUM} = 2K_{Shl} \quad (6)$$

Normal sounding hummel array curves :

IN hummel array we can write:

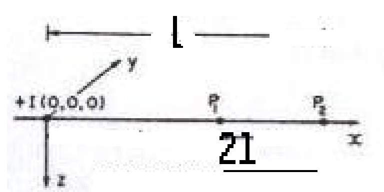

Figure 3 .hummel array

$$\begin{cases} r_1 = L - l \\ r_3 = L + l \\ r_2 = r_4 = \infty \end{cases} \quad (7)$$

$$\Delta V = \frac{I\rho_1}{2\pi}\left(\frac{1}{L-l} - \frac{1}{L+l}\right) + 2\sum_{n=1}^{\infty} K_{12}^{n}\left\{\frac{1}{(L-l)\left\{1+(2nh1)^2/(L-l)^2\right)^{\frac{1}{2}}} - \frac{1}{(L-l)\left\{1+(2nh1)^2/(L+l)^2\right\}^{\frac{1}{2}}}\right. (8)$$

$$\rho a = \rho 1[1 + \left(\frac{L+l}{l}\right)\sum_{n=1}^{\infty} \frac{k_{12}^{n}}{\left\{1+(2nh1/L-l)^2\right\}^{\frac{1}{2}}} - \left(\frac{L-l}{l}\right)\sum_{n=1}^{\infty} \frac{k_{12}^{n}}{\left\{1+(2nh1/L+l)^2\right\}^{\frac{1}{2}}}] (9)$$

If L>>ℓ we can write

$$\frac{1}{\left\{(L-l)^2+(2nh1)^2\right\}^{\frac{1}{2}}} - \frac{1}{\left\{(L+l)^2+(2nh1)^2\right\})^{\frac{1}{2}}} \approx \frac{2l}{\left\{L^2+(2nh1/L)^2\right)^{\frac{3}{2}}}$$

$$\Delta V = \frac{I\rho_1 l}{\pi L^2}\left[1 + 2\sum_{n=1}^{\infty} \frac{k_{12}^{n}}{\left\{1+(2nh1/L)^2\right\})^{\frac{3}{2}}}\right] \approx \frac{I\rho_1 l}{\pi L^2}(1+2D_{CRP})$$

$$\Delta V = \frac{I\rho}{2\pi}\left\{\left(\frac{1}{Am} - \frac{1}{Bm}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right\}$$

$$\rho a = \frac{2\pi\Delta V}{I}\frac{1}{\left(\frac{1}{L-l} - \frac{1}{L+l}\right)}$$

$$\rho a = \rho_1[1 + 2\sum_{n=1}^{\infty} \frac{k_{12}^{n}}{\left\{1+(2nh1/L)^2\right\}^{\frac{3}{2}}}]$$

$$\frac{\rho a}{\rho 1} = 1 + 2\sum_{n=1}^{\infty} \frac{K_{12}^{n}(L/h_1)^3}{\left\{(l/h_1)^2 + (2n)^2\right\}^{\frac{3}{2}}} (10)$$

In schlumberger array we can write:

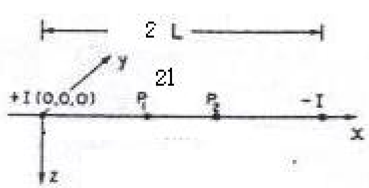

Figure 4. schlumberger array

$$r_1 = r_4 = L - l$$
(11)
$$r_2 = r_3 = L + l$$

$$\Delta V = \frac{I\rho_1}{2\pi}\left[\left(\frac{2}{L-l} - \frac{2}{L+l} + 4\sum_{n=1}^{\infty} k_{12}^n \left\{\frac{1}{(L-l)\{1+(2nh)^2/(L-l)^2)\}^{\frac{1}{2}}}\right.\right]-\left\{\frac{1}{(L-l)\{1+(2nh_1)^2/L+l)^2)\}^{\frac{1}{2}}} =$$

$$\frac{I\rho_1 2l}{\pi(L^2-l^2)}\left[1+\left(\frac{L+l}{l}\right)\sum_{n=1}^{\infty}\frac{k_{12}^n}{\{1+(2nh_1)^2/L-l)^2)\}^{\frac{1}{2}}} - \frac{(L-l)}{l})\sum_{n=1}^{\infty}\frac{k_{12}^n}{\{1+(2nh_1)^2/L+l)^2)\}^{\frac{1}{2}}}\right](12)$$

If L>>ℓ we can write:

$$\frac{1}{\{(L-l)^2+(2nh1)^2\}^{\frac{1}{2}}} - \frac{1}{\{(L+l)^2+(2nh1)^2\}^{\frac{1}{2}}} = \frac{2l}{L^2\left\{(L+1)^2+\left(\frac{2nh}{L}\right)^2\right\}^{\frac{3}{2}}}$$

$$\Delta V = \frac{I\rho_1 2l}{\pi L^2}\left(1+2\sum_{n=1}^{\infty}\frac{k_{12}^n}{\{(1+(2nh1/L)^2\}^{\frac{3}{2}}}\right) \approx \frac{I\rho_1 2l}{\pi L^2}(1+2D'S)$$

$$\rho_a = \frac{2\pi\Delta V}{I}\frac{1}{\left\{\frac{1}{L-l}-\frac{1}{L+l}\right\}-\left\{\frac{1}{L+l}-\frac{1}{L-l}\right\}} = \frac{2\pi\Delta V}{I}\frac{1}{\left(\frac{2}{L-l}-\frac{2}{L+l}\right)}$$

If L>>ℓ we can write:

$$\rho_a = \rho_1[1+2\sum_{n=1}^{\infty}\frac{k_{12}^n}{\left\{1+\left(2nh_1/L\right)^2\right\}^{\frac{3}{2}}}$$

$$\frac{\rho_a}{\rho_1} = 1+2\sum_{n=1}^{\infty}\frac{k_{12}^n\left(\frac{L}{h_1}\right)^3}{\left\{\left(L/h_1\right)^2+(2n)^2\right\}^{\frac{3}{2}}}(13)$$

Comparison between apparent resistivity hummel array and schlumberger array indicates that apparent resistivity both array is equal . thus the resistivity data from such measurements can be interpreted as normal sounding schlumberger array curves and both method interpretation is same.

Comparison between depth of investigation in hummel and schlumberger arrays

Formolaes for depth of investigation (roy and apparao1971) are:

$$V_{P_1P_2} = \int_{Z=0}^{\infty} DIC = \frac{\rho I}{2\pi}\left[\frac{1}{a}-\frac{1}{b+c}-\frac{1}{a+b}+\frac{1}{c}\right](14)$$

$$DIC = \int_{x=y=-\infty}^{x=y=+\infty} dV_{p1p2} = \frac{\rho I}{4\pi^2} dz[\frac{8\pi z}{(a^2+4z^2)^{\frac{3}{2}}} - \frac{8\pi z}{\{(b+c)^2+4z^2\}^{\frac{3}{2}}} - \frac{8\pi z}{\{(a+b)^2+4z^2)\}^{\frac{3}{2}}} +$$

$$\frac{8\pi z}{(c^2+4z^2)^{\frac{3}{2}}} (15)$$

$$DIC_{(N)} = \frac{DIC}{V_{P_1P_2}} (16)$$

From formolaes above we get :

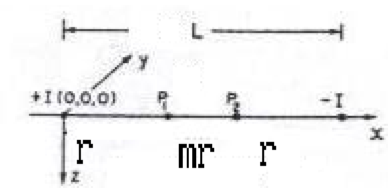

Figure 5.schlumberger array

$$DIC_{(N)_{schl}} = \frac{DIC}{V_{\rho_1\rho_2}} = \frac{(1+m)l}{(2+m)m}.4zdz\left[\frac{1}{\left\{(\frac{l^2}{(2+m)^2}+4z^2)^{\frac{3}{2}}\right\}} - \frac{1}{\left\{(\frac{(1+m)^2 l^2}{(2+m)^2}+4z^2)^{\frac{3}{2}}\right\}}\right] (17)$$

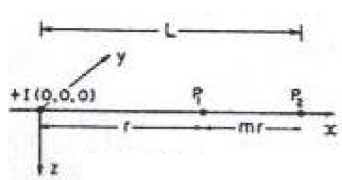

Figure 6 . hummel array

$$DIC(N)hum = \frac{4Lzdz}{m}\left[\frac{1}{(\frac{l^2}{(1+m)^2}+4z^2)^{\frac{3}{2}}} - \frac{1}{\left\{l^2+4z^2)^{\frac{3}{2}}\right\}}\right] (18)$$

With using from two formulaes above and diagrams bellow the values of depth of investigation for schlumberger and hummel arrays are collected in table 1 :

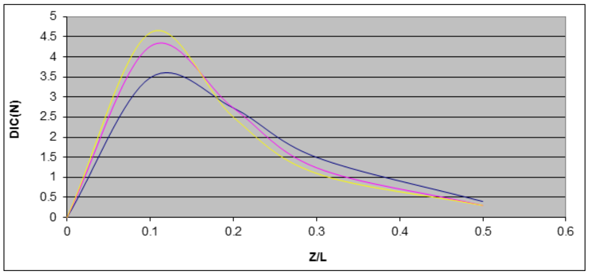

Figure 7 .Depth of investigation for schlumberger array for m=0.5 , 1.5 , 2

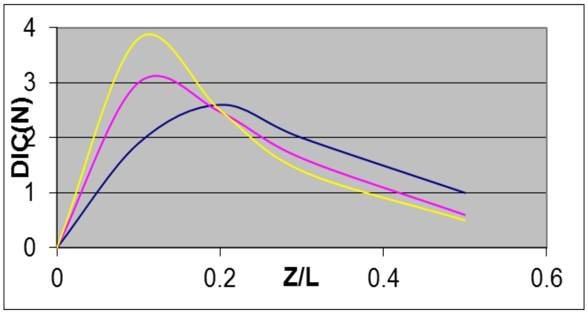

Figure 8. Depth of investigation for hummel array for m=0.5 , 1.5 , 2

Table 1

m	hummel	schlumberger
2	0.112	0.085
1.5	0.132	0.095
0.5	0.195	0.120

Therefore , we give conclusion that depth of investigation hummel array is more schlumberger array.

Definition of the limiting depth of detection:

The limiting depth of detection (L.D.D) of a body is the maximum depth up to which the body can be detected from the surface.

The limiting depth of detection depends upon the (1) size of the target body (2) its resistivity contrast with the surrounding host rocks (3) type spacing of the different electrode systems (4) instrumental noise (5) geological noise. Comparison of the limiting depth of the detection between hummel and schlumberger arrays:

The limiting depth of detection based on that assumption are presented in table (2) for hummel and schlumberger arrays :

Table 2. Limiting depth of detection

Electrode configuration	Resistivit bed	conductive bed
hummel	1.17L	6.6L
schlumberger	0.58L	0.90L

This computed L.D.D 's are the maximum limits for detection.
Field tests : in south GORGAN area is done three sounding in one point with distances electrode same.

1: sounding one: this sounding surveyed with schlumberger array.

Geometric factor calculated from formulae

$$K = \pi \frac{AM.AN}{MN} \quad (19)$$

And determined apparent resistivityfrom formulae

$$\rho = \frac{K \Delta V}{I} \quad (20)$$

Table changes apparent resistivity for schlumberger array are collected in table 3 below and its curve be shown :

Table 3

OA=AB/2	MN	ρ
2	0.6	46.5
2.5	0.6	53
2.6	0.6	57
3.7	0.6	72.7
3.7	1	62.5
4.5	0.6	85
4.5	1	72.8
7	1	83.7
10	1	89
10	3	87
15	1	89
15	4	73
20	4	54.8

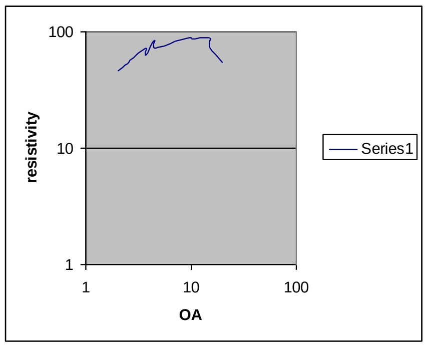

Figure 9 . diagram of schlumberger array

2 : sounding two : this sounding surveyedhummel array .

Current electrode A is located to direction east and electrode B fixed in infinity (OB=300m, AMN) . table changes apparent resistivity for hummel array are collected in table 4 below and its curve be shown .

Table 4

OA=AB/2	MN	ρ
2	0.6	49
2.5	0.6	54
2.6	0.6	56
3.7	0.6	70.2
3.7	1	60
4.5	0.6	83
4.5	1	72.2
7	1	83.5
10	1	93
10	3	89.7
15	1	83
15	4	79.9
20	4	54.9

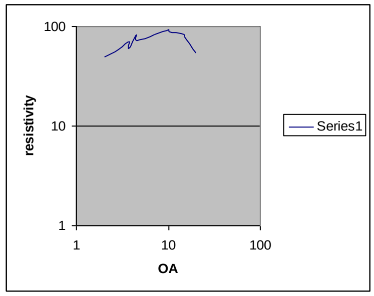

Figure 10.diagram of hummel array (AMN)

With comparison thicknesses and apparent resistivities are shown two curves above (fig.9 and fig.10) are similar with good accuracy and RMS = 0.07%

3: sounding three: this sounding surveyed hummel array .

Current electrode B is located to direction weast and electrode A fixed in infinity (OA=300m , MNB). table changes apparent resistivity for hummel array are collected in table 5 below and its curve be shown .

Table 5

OA=AB/2	MN	ρ
2	0.6	43.6
2.5	0.6	52.6
2.6	0.6	57.4
3.7	0.6	74.8
3.7	1	65
4.5	0.6	88.5
4.5	1	76.7
7	1	84.1
10	1	84
10	3	83
15	1	75
15	4	74
20	4	57

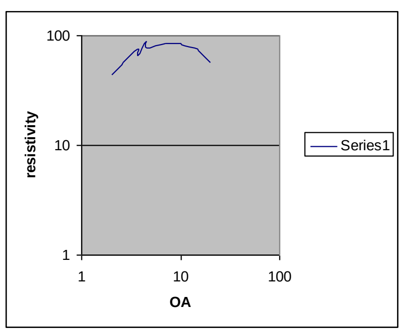

Figure 11 . diagram of hummel array(MNB)

With comparison thicknesses and apparent resistivities are shown two curves above (fig .9 and fig.11) are similar with good accuracy and RMS = 0.3%

Consider values of calculation in this two case(hummel array) have a little difference with before case(schlumberger array) , but medium this two values of apparent resistivity hummel array is equal with schlumberger array. This means that :

$$\rho_{a_{Sch}} = \frac{\rho_{aA} + \rho_{aB}}{2} \quad (21)$$

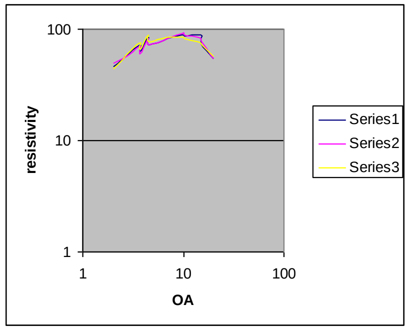

Figure 12 .comparison between diagrams hummel arrays(AMN ,MNB) with schlumberger array.

CONCLUSION

1) with hummel array are shown fractures (faults , dykes , …) better from schlumberger array.
2) apparent resistivity is equal for both array , therefore the resistivity dataes from such measurements can be interpreted as normal sounding schlumberger curves.
3)Depth of investigation of hummel array is more from schlumberger array.
4) Limiting depth of detection of hummel array is more from schlumberger array.

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