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Some Physical Properties of Different Types of Rocks

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ABSTRACT

The norm of elastic constant tensor and the norms of the irreducible parts of the elastic constants of different types of rocks (Shaley sand, Sandstone, Shale, Dol.Shale) which are taken from different wells at different depths are calculated. The relation of the scalar parts norm and the other parts norms and the anisotropy of these rocks are presented. The norm ratios are used to study anisotropy of these rocks, and the relationship between the anisotropy of these rocks and other physical properties is represented.

Keywords : Rocks, Isotropy, Norm, Anisotropy, and Elastic Constants.

I. INTRODUCTION

Rocks being a composite material consisting of a large number of different minerals, the effective modulus values therefore are dependent upon the contribution of these individual minerals, their relative proportion, shape and orientation. Theoretical analysis of treating rock as a composite material has been limited only to a two-phase system where it is assumed that it consists of elastic granular inclusions surrounded by a matrix having different elastic properties. A number of equations have been developed by various investigators (Paul, 1960, Hashin, 1962, Greszzus, 1966, Lama, 1965, Ko and Haas, 1972). Their application to rocks has not been proved because of obvious reasons, but these do help to demonstrate the modulus anisotropy in rocks which have preferred of grains of elongated shapes [1]. The decomposition procedure and the decomposition of elastic constant tensor (Elastic constant tensor can be decomposed into two scalar parts, two deviator parts and one nonor part) is given in [2-3], also the definition of norm concept and the norm ratios and the relationship between the anisotropy and the norm ratios are given in [2-5]. As the ratio N_s/N (Norm of the scalar part of the elastic constant tensor/Norm of the elastic constant tensor) becomes close to one the material becomes more isotropic, and as the sum of the ratios N_d/N (Norm of the deviator part of the elastic constant tensor/Norm of the elastic constant tensor) and N_n/N (Norm of the nonor part of the elastic constant tensor/Norm of the elastic constant tensor) becomes close to one the material becomes more anisotropic as explained in [2-5].

II. DATA AND CALCULATIONS

Table 1. Elastic Constants (GPa), [5]

Well Name	Depth (feet)	Density (Dry)	Density (sat)	C_{11}	C_{12}	C_{33}	C_{44}	C_{13}	C_{66}	ε, (%)	γ ($)	Φ ($)	Rock Type
Well 1*	6303	2.35	2.44	3.77	0.88	2.5	0.93		1.45	25	27	9	Shaley sand.
After Saturation				3.86	1.6	2.73	0.7		1.13	21	31		

Well-1	6384	2.29	2.4	3.22	0.7	2.27	0.99		1.26	21	13	12	Shaley sand.
Well-1	7148	1.85	2.03	2.36	0.46	1.96	0.82	0.39	0.93	10	7	18	Sandstone
Well-2*	6893	2.27	2.37	3.16	0.51	2.61	1.15	0.46	1.29	10	6	11	Sandstone
After Saturation				3.66	1.29	3.32	0.99	1.28	1.19	5	10		
Well-3	6894	2.26	2.36	2.98	0.51	2.43	1.09	0.97	1.2	11	5	10	Sandstone
Well-4	7017	2.44	2.51	4.11	0.87	3.95	1.55	-0.42	1.6	2	1	6	Sandstone
Well-5	6369	2.14	2.32	3.06	0.64	2.22	0.91	-0.68	1.21	19	17	17	Sandstone
Well-6	6349	2.3	2.43	3.25	0.76	2.06	0.94		1.25	29	16	12	Shaley sand.
Well-6	6347	2.29		3.05	0.56	2.26	1.02		1.25	18	11		Shaley sand.
Well-7	6782	2.48		3.1	0.08	2.58	1.2		1.48	10	11		Shale
Well-8	6830	3.03		10.46	3.75	8.8	2.82		3.35	9	9		Dol.Shale
Well-10*	4441	2.1	2.29	2.47	0.51	2.07	0.86	0.26	0.98	10	7	18	Sandstone
After Saturation				2.59	0.95	2.61	0.76	0.75	0.82	0	4		
Well-10	4491	2.42		3.72	0.78	2.15	0.91		1.47	37	31		Shale
Well-10	4492	2.78	2.77	10.35	3.93	7.5	2.54	1.93	3.21	19	13		Dol.Shale
Well-10	4494	2.39		3.51	0.69	2.33	0.99		1.41	25	21		Shale

In the above table Stiffnesses in dry and saturated specimens at reservoir pressure conditions for rock specimens from different oil well in the area. (*) Sandstone specimens tested in dry and saturated conditions. Φ is the porosity and ε and γ ar the Vp-anisotropy and the Vsh-anisotropy, respectively.

By using and the decomposition of the elastic constant tensor, we have calculated the norms and the norm ratios as is shown in table 2.

Table 2. the norms and norm ratios

Well Name	**Rock Type**	N_s	N_d	N_n	N	$\frac{N_s}{N}$	$\frac{N_d}{N}$	$\frac{N_n}{N}$	**Sum of the last two columns**
Well 1*	Shaley sand.	6.384	1.186	0.304	6.501	0.9821	0.1825	0.0468	0.2293
After Saturation		7.296	1.035	0.227	7.373	0.9896	0.1404	0.0308	0.1712
Well-1	Shaley sand.	5.617	0.817	0.050	5.677	0.9895	0.1440	0.0088	0.1528
Well-1	Sandstone	4.216	0.358	0.101	4.236	0.9961	0.0846	0.0238	0.1084
Well-2*	Sandstone	5.635	0.475	0.101	5.657	0.9963	0.0839	0.017	0.1009
After Saturation		7.061	0.417	0.143	7.074	0.9981	0.0589	0.0202	0.0791
Well-3	Sandstone	5.680	0.532	0.347	5.716	0.9938	0.0930	0.0607	0.1537
Well-4	Sandstone	7.010	1.254	1.041	7.197	0.974	0.1742	0.1447	0.3189
Well-5	**Sandston**	**4.625**	**1.464**	**1.153**	**4.987**	**0.9275**	**0.2936**	**0.2312**	**0.5248**

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Well-6	Shaley sand.	5.579	1.008	0.013	5.670	0.9840	0.1778	0.0023	0.1801
Well-6	Shaley sand.	5.353	0.683	0.043	5.396	0.9919	0.1265	0.0080	0.1345
Well-7	Shale	5.425	0.529	0.276	5.4583	0.9940	0.0969	0.0506	0.1475
Well-8	Dol.Shale	17.057	3.816	3.067	17.746	0.9612	0.2151	0.1728	0.3879
Well-10*	**Sandstone**	**4.340**	**0.440**	**0.223**	**4.368**	**0.9936**	**0.1007**	**0.0510**	**0.1517**
After Saturation		**5.217**	**0.049**	**0.100**	**5.218**	**0.9998**	**0.0093**	**0.0191**	**0.0284**
Well-10	Shale	6.079	1.416	0.257	6.247	0.9731	0.2267	0.0412	0.2679
Well-10	**Dol.Shale**	**17.697**	**3.243**	**1.472**	**18.052**	**0.9803**	**0.1796**	**0.0815**	**0.2611**
Well-10	Shale	5.925	1.064	0.192	6.023	0.9838	0.1766	0.0319	0.2085

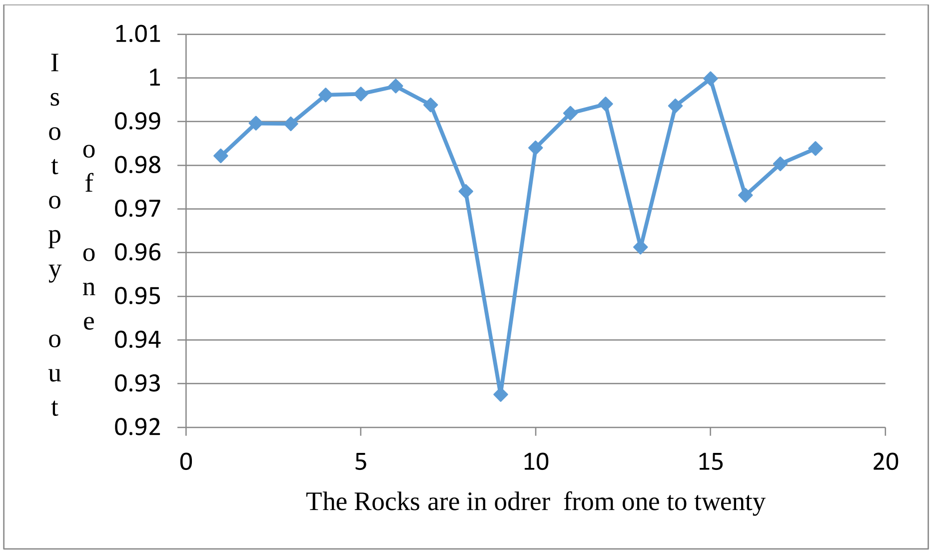

Figure 1. Isotropy Degree.

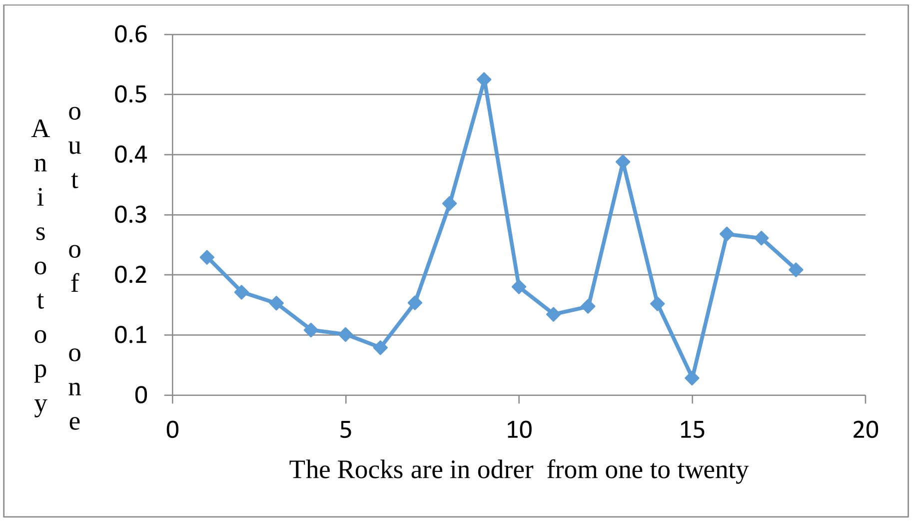

Figure 2. Anisotropy Degree.

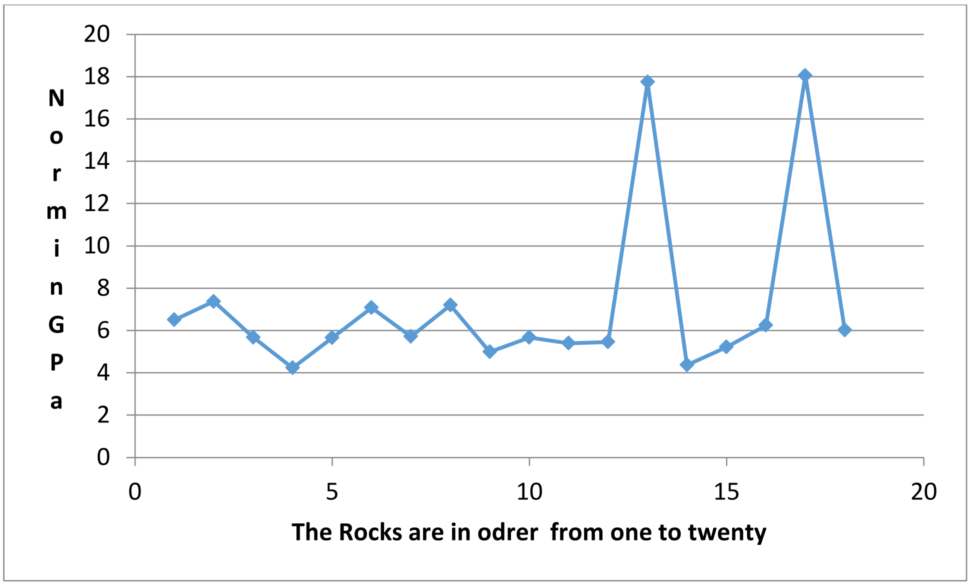

Figure 3. Elastically Srong.

III. CONCLUSION AND RESULTS

From table 2 and the Figures (Figure 1 to Figure 3), and analyzing the ratio Ns /N we can conclude that the rock sandstone from well – 10 at depth 4441 feet after saturation with saturated density 2.29 is the most isotropic rock with highest value of Ns /N (0.9998) and lowest sum value of Nd /N and Nn /N (0.0284), and the rock sandstone from well – 5 at depth 6369 feet with dry density 2.14 is the most anisotropic rock with highest sum value of Nd /N and Nn /N (0.5248) and with lowest value of Ns /N (0.9275), because for isotropic material Ns /N = 1, and Nd /N = 0 and Nn /N = 0. Which means that as sum values of Nd /N and Nn /N increases the anisotropy increases. And also the elastically strongest rock is Dol.Shale from well – 10 at depth 4452 with dry density 2.78 and saturated density 2.77, which has the highest value of. N (18.052), and the elastically lowest strongest is the rock sandstone from well – 10* at depth 4441 feet with dry density 2.1 and saturated density 2.299, which has the lowest value of N (4.368).

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