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DETERMINATION OF THE RHEOLOGICAL PROPERTIES OF DRILLING FLUID FROM LOCALLY SOURCED CLAY FROM VARIOUS GEOGRAPHICAL AREAS

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ABSTRACT

The rheological formulation of our locally sourced bentonite clay in substitute for the imported foreign bentonite clay was carried out by the comparative analysis of the parameters of the local mud with the stipulated API standard values to ascertain the level of compliance in drilling operation. The local muds P^H values responded positively on beneficiation with 1.0g of potash, the modification raised the muds P^H values to fall within the standard range of 9.5 to 12.5. The viscosity of the local muds was seen to be slightly below the standard requirement of 30cp, but appreciated favorably to the standard requirement when beneficiated with 1.0g of drispac. On beneficiating the foreign aqua gel bentonite muds, with the same quantity of additives used on other mud samples, there was an excessive abnormal increase in its viscosity for instance the viscosity of 17.5g of the foreign mud was drastically raised from 17.1cp to 210.5cp at 600 dial reading. It was obvious that most of the prepared local mud samples parameters such as the sand percentage composition, power law index, density, marsh funnel viscosity, etc met the minimum required specifications, while other few parameters such as the theological properties, needed some additive treatment for favorable comparison with the foreign clay mud properties. Therefore, the utilization of these clays for any industrial application will pose no harm to surface and surface facilities and will in no turn represent a value added to the Nigeria economy by the total prevention of the important of high quality activated foreign bentonite clay. Tests and analysis were carried out on Local Clay samples obtained from a town in delta state, imo state and the foreign commercial bentonite. This research is to evaluate the performance of the Local clay samples for drilling operations in Nigeria. The rheological and the thixotropic properties as well as other parameters of the Local clay mud was seen to have improved, but however, when beneficiated with chemical additives of different concentrations, there was an increase in the overall parameters of the Local mud samples, making them ideal for any industrial application as their parameters met with the stipulated standard specifications of API, OCDA.

INTRODUCTION

This paper basically details on the rheological formulation of our locally sourced bentonite clay in substitute for the imported foreign bentonite clay. This is achieved by the comparative analysis of the parameters of the local mud with the stipulated API standard values to ascertain the level of compliance in drilling operation. The properties of a drilling fluid can be grouped under the categories: Rheological properties, gel strength (thixotropic) properties, filtration property and mud weight property. In geology, rheology is defined as the study of how matter deforms the flows, including its elasticity, plasticity and viscosity. Bentonite is a major additive, which gives the proper rheological (non Newtonian shear thinning) and filtration(**Mihalakis, Th.S.et al**). In drilling fluids it is the study of the deformation and flow of matter. The term is also used to indicate the

properties of a given fluid, as in mud rheology. Rheology is an extremely important property of drilling muds, work-over and completion fluids, cements and specialty fluids and pills. Mud rheology is measured on a continual basis while drilling and adjusted with additives or dilution to meet the needs of the operation. In water-base fluids, water quality plays an important role in how additives perform. Rheology is a broad term that means the study of the deformation of materials, including flow. This is a property of mud that has received widespread attention, and it's sometimes referred to as the flow characteristics of drilling fluid. There are four points to be considered in the study of mud rheology. These points basically form the rheological properties of drilling fluid. (i)Apparent viscosity (AP) (ii) Plastic viscosity (PV) (iii) Yield point (YP) (iv)Gel strength
The rheological of a drilling mud depends largely on the type of fluid; drilling fluid can be categorized into two general types, (i)Newtonian fluids
(ii)Non-Newtonian fluids (**Australian Drilling industry training committee Ltd**)
This work is to determine the effective nature of our local content formulated in producing drilling fluid, its resulting problems and prospects. The research intends specifically to:

- Identify a drilling fluid as a fundamental component which plays series of vital roles in effective drilling of an oil and gas well.
- Suggest other ways of sourcing materials locally for the formulation of drilling fluid.
- Detailed analysis is down on the samples of our locally formulated mud and its result is compared with that of the foreign.
- Examination of a drilling fluid to determine its adequacy in carrying out its fundamental role in the drilling of oil and gas well.
- Recommend measures to ensure the maximum utilization of our local bentonite clay over the imported foreign bentonite clay.

1.2 STATEMENT OF PROBLEM

Nigeria is a major oil producer and therefore embarks on substantial drilling activities. The drilling activities for the development of petroleum and underground water resources are indeed consuming large quantities of clay for drilling mud preparations, of which are being imported. However, the determination of the suitability of our local clay mud, which is the basis of this study, will stop at leaving no stone unturned in ensuring that the commercial acceptability of the local clays as they meets with the standard specifications for oil well drilling mud. This is aimed at eradicating the problems created through the importation of foreign bentonite clay.

PREPARATION OF DRILLING FLUID

Drilling fluid is made up of water, clay and chemical additives. The major constituent of most drilling fluid is water. Therefore, the source of the make-up water is an important consideration in the selection of mud program, because the quantity, quality and on-site cost of the water used for the preparation of mud may affect the selection and performance of the mud. The procedures and measurements used in the preparation of laboratory barrels of the mud samples for analysis are given below(**Okorie, O.M)**:

TESTING FOR DENSITY (MUD WEIGHT)

The mud density test was conducted in order to determine the weight per unit volume of the mud. Mud density must be great enough to provide sufficient hydrostatic heat to prevent influx of formation fluids, but not so great to cause loss of circulation, damage to the drilled formation, or reduce the rate of penetration (ROP). This test is done to determine whether the prepared local mud samples possess API minimum required weight for oil well drilling.

TESTING FOR MARSH FUNNEL VISCOSITY (MFV)

This test is done to obtain the marsh funnel viscosity of the different mud samples using a marsh funnel viscometer and a graduated cup.

TESTING FOR PLASTIC VISCOSITY (PV), YIELD POINT (yp), AND GEL STRENGHT OF MUD SAMPLES

The result of the funnel viscosity test is called the funnel viscosity of the mud. The viscosity of a mud is made up of two variables: plastic viscosity (PV) and yield point (yp). These values, as well as timed gel strength, were measures with the direct – indicating viscosity.

TESTING FOR HYDROGEN 1ON (P^H) OF MUD SAMPLES

The degree of acidity or alkalinity of mud is indicated by the hydrogen ion concentration, which is commonly expressed in terms of P^H. A neutral mud has a P^H of 7.0. An alkaline mud has P^H readings ranging from just above 7 for slight alkalinity, to 14 for the strongest alkalinity, Acid mud range from just below 7 for slight acidity, to less than I for the strongest acidity. P^H measurements aid in determining the need for chemical control of the mud, and indicates the presence of contaminates such as cement and gypsum. The appropriate P^H of drilling mud varies with the mud type(**George, R and Darlry, H.C)**.

TESTING FOR SAND CONTENT OF MUD

By definition, solid particles larger than 74 micros (200 mesh) are classified as API sand. (A micron is one – million inch of a meter there are about 25, 400 microns to an inch) regular determination of the sand content of drilling muds is necessary because these particles can be highly abrasive, and can cause excessive wear of pump parts, drill bits, and pipe connections, excessive sand may also result in the deposition of a thick filter cake on the walls of the hole, or it may settle in the hole around the tools when circulation is temporarily halted, interfering with the operation of drilling tools of settling casing. The sand content test for set is used in the test for sand content determination.

TESTING FOR THE SWELLING INDEX OF CLAY SAMPLES

The swelling index referrers to the ratio of the measure of the yield of clay in water when a give volume of water is poured in a given volume of clay over a period of time, usually between 24 to 96 hours, the swelling index of clay examines the tendency of our local clay to hydrate within a given period of time. This test is to determine the value of the swelling index of the clay samples, to obtain its swelling ability for mud preparation.

TABLE 1.0 RESULTS OF THE SWELLING INDEX OF THE CLAY SAMPLES

CLAY TYPE	DAY 1	DAY 2	DAY 3	DAY 4
Akokwa clay sample	$\frac{11.2}{14.8} = 0.75$	$\frac{12.0}{14.0} = 0.85$	$\frac{14.0}{13.0} = 1.76$	$\frac{14.8}{12.2} = 1.21$
Akperhe – olomu clay sample	$\frac{11.0}{14.0} = 0.78$	$\frac{12.0}{12.0} = 1.0$	$\frac{12.5}{11.5} = 1.08$	$\frac{14.8}{12.2} = 1.21$

Baroid Nig clay sample	$\frac{15.8}{12.5} = 1.26$	$\frac{21.0}{6.0} = 3.5$	$\frac{22.0}{5.0} = 4.4$	$\frac{22.3}{14.1} = 5.4$
Foreign Aqua gel bentonite clay sample	$\frac{226.0}{4.5} = 5.7$	$\frac{30.0}{1.0} = 30$	$\frac{37.0}{1.0} = 37.0$	$\frac{42.0}{0.4} = 105$

THE API STANDARD TESTE AND ANALYSIS VALUES OF MUD PARAMETERS
TABLE 2.0

MUD PARAMETERS	NUMERICAL VALUE REQUIREMENT
Mud density (Ib/gal)	8.65 – 9.60 (min & max)
Viscometer dial reading at 600 rpm	30cp (minimum)
Plastic viscosity (cp)	8 – 10
Yield point (Ib/100ft^2	3 x plastic viscosity
Fluid loss	15.0ml (maximum)
pH level	9.5 (min) – 12.5 (max)
Sand content	1 – 2% (maximum)
Screen analysis	4 (maximum)
Moisture content	10% (maximum)
Ca^{2+} (ppm)	2.50 (maximum)
Marsh funnel viscosity	52 – 56 sec/q+
Mud yield (bbi/ton)	91 (maximum)
Api filtrate (ml)	30 (minimum)
Montmorillonite	70 – 130
Vermiculite	100 – 200
Illite	10 – 40
Kadinite	3 – 15
Chlorite	10 – 40
Marsh funnel viscosity for water	26 sec/q+ ± 0
"N" – factor (power law index)	1 (maximum)
Yp/pv ratio	3.0 (maximum)

COMPUTATION OF MUD SAMPLES PRACTICAL RESULTS WITHOUT BENEFICIATION

This section details on the computation of mud samples practical results without beneficiation. Calculation of the AV, PV, YP, "n" and "k" values of mud samples of different concentration as 17.5g, 21.0g and 24.5g are done using the formula(**Alan J. Smith)**:

Apparent Viscosity, AV= $\frac{Dial\ reading\ at\ Ø600}{2}$ ----------- 1

Plastic Viscosity,PV = 600 dial reading – 300 dial reading

PV = Ø 600 – Ø 300 ----------------------- (2)

Yield Point,YP = 300 dial reading – plastic Viscosity

YP = Ø 300 – PV --------------------------- (3)

Power law index, "n" = 3.32 log (R_2/R_1) -------------------- (4)

Where R_2 = Ø 600 reading, R_1 = Ø 300 reading.
Consistency index, "K" = 5.1 x R_2/Y^n --------------------------------- (5)

KOKWA TOWN MUD SAMPLE

i. With mud concentration of 17.5g

From equation (1) above we have that;

AV= $\frac{Ø600}{2} = \frac{2.7}{2}$ = 1.35cp

From equation (2) above we have that;

PV = Ø 600 – Ø 300
=2.7-1.9 = 0.8cp

From equation (3) above we have that;

YP = Ø 300 – PV
= 1.9 – 0.8 =1.1 Ib/100ft^2

From equation (4) above we have that;

"n"= 3.32 log (R_2/R_1)
=3.32 log $\left[\frac{2.7}{1.9}\right]$ = 0.50

From equation (5) above we have that;

"K"= 5.1 x R_2/Y^n

When Y = 511 ∴ "K" = 5.1 x 2.7/511$^{0.50}$ = "K" = 0.60

When Y = 1022 ∴ "K" = 5.1x2.7/1022$^{0.50}$ = "K" = 0.43

Mud sand % composition = 0.28%

Mud density value = 8.61 Lb/gal

Mud pH value = 5

10 second gel strength = 0.1

10 minute gel strength = 0.1

Mud temperature value = 77.7^{0}f (25.3^{0}C)

The calculation is repeated with different mud concentrations. The results given in tables;3.0,4.0 ,5.0 and 6.0

TABLE 3.0 AKOKWA MUD SAMPLE PARAMETERS BEFORE BENEFICIATION

Mud	Viscometer		Mud gel		Consistency		Mud	Mud	Mud	Mud	Power	Mud	Mud	Mud	Mud
Conc.	Readings		strength		index ("K")		AV	YP	AV	YP	law	density	MFV	Temperature	Sand
(g)	(centipoises)				(dyne sec/cm^3)		(CP)	(CP)	(CP)	(Ib/100ft^2)	Index ("n")	(Ib/gal)	(sec/q+)	(^{0}C)	%
	Ø600	Ø300	10 sec	10 min	qt 511	qt 1022									
17.5g	2.7	1.9	0.1	0.1	0.60	0.43	0.8	1.35	1.1	5	0.5	8.61	25.5	25.3	0.28
21.0g	2.1	1.4	0.1	0.2	0.32	0.22	0.7	1.05	0.7	5	0.56	8.70	24.9	25.4	0.344
24.5g	2.6	1.8	0.3	0.3	0.58	0.04	0.8	1.30	1.0	5	0.50	8.92	25.1	24.7	0.382

Table:4.0 AKPERHE OLOMU MUD SAMPLES PARAMETERS BEFORE BENEFICATION

Mud	Viscometer		Mud gel		Consistency		Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud
Conc.	Readings		Strengths		Index "K"		PV	AV	YP	P^H	Density	Power Low Index	mfv	sand	Temp.
(9)	(centipoise)		(Sec/Min)		(dynesec/cm^3)		(CP)	(CP)	(Ib/100ft^2)	Value	(Ib/gal)	("n")	(sec/qt)	(%)	(^{O}C)
	Ø600	Ø300	10sec	10min	@ 511	@1022									
17.5	2.4	1.7	0.2	0.2	0.54	0.38	0.7	1.2	1.0	5	8.47	0.50	25.2	0.250	25.2
21.0	2.6	2.0	0.2	0.2	1.24	0.95	0.6	1.3	1.4	5	8.60	0.38	26.0	0.252	25.4
24.5	2.7	2.0	0.1	0.3	0.94	0.7	0.7	1.4	1.3	5	8.60	0.43	26.0	0.375	26.6

Table:5.0 Baroid Nigeria Mud Samples Parameters before Beneficiation

Mud	**Viscometer**		**Mud gel**		**Consistency**		**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**
Concen-Tration	**Readings**		**Strengths**		**Index "K"**		**PV**	**AV**	**YP**	**PH**	**Density**	**Power Low Index**	**mfv**	**sand**	**Temp**
(9)	(centipoise)		(Sec/Min)		(dynesec/cm3)		(CP)	(CP)	(Ib/100ft2)	Value	(Ib/gal)	("n")	(sec/qt)	(%)	(OC)
	Ø600	Ø300	10sec	10min	@ 511	@1022									
17.5	1.9	1.1	0.1	0.1	0.07	0.04	0.8	0.95	0.3	6	8.50	0.80	25.6	0.32	24.0
21.0	2.3	1.1	0.0	0.0	0.015	0.0075	1.2	1.15	-0.1	6	8.53	1.06	26.9	0.32	25.2
24.5	3.0	1.1	0.2	0.1	0.002	0.0008	1.9	1.5	-0.8	6	8.65	1.42	26.0	0.35	24.0

Mud	**Viscometer**		**Mud gel**		**Consistency**		**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**	**Mud**
Concentration	**Readings**		**Strengths**		**Index "K"**		**PV**	**AV**	**YP**	**P^H**	**Density**	**Power Low Index**	**mfv**	**sand**	**Temp.**
(9)	(centipoise)		(Sec/Min)		(dynesec/cm^3)		(CP)	(CP)	(Ib/100ft^2)	Value	(Ib/gal)	("n")	(sec/qt)	(%)	(^{O}C)
	Ø600	Ø300	10sec	10min	@ 511	@1022									
17.5	17.7	10.2	0.1	1.5	0.65	0.38	7.5	8.9	2.7	9.0	8.70	0.79	42	0.30	25
21.1	21.1	11.6	0.2	5.1	3.27	2.22	9.5	10.6	2.1	9.0	8.70	0.56	44	0.30	25.2
24.5	31.4	18.5	0.7	12.1	1.39	0.83	12.9	15.7	5.6	9.0	8.70	0.76	46	0.30	25

Table: 6.0 FOREIGN AQUAGEL BENTONITE MUD SAMPLES PARAMETERS BEFORE BENEFICIATION

BENEFICIATION OF MUD SAMPLES:

Beneficiation is the treatment of the prepared mud samples with chemical enhancers such as viscosifiers, weighting materials (densifiers), thinners, and pH raiser to improve the mud parameters for proper industrial application of the mud samples. The blending of the additives (beneficiation) can be done wet or dry. Dry additive blending has proved to be better than wet blending in some clay samples. Dry blending is achieved by an accurate measurement of dry clay and additives in a mixer. For wet blended with 350ml of fresh water and allowed to hydrate. If the wet blend is not adequately hydrated, the mixture will lack homogeneity. The mud samples used for this investigation was subjected to 24 hours aging period to ensure clay hydration for a homogeneous mixture or suspension. It is important to obtain a homogeneous mixture in order to obtain retain ability of treatment. Retain ability is the mud's ability to remain viscous or thinned and maintain the attained level of viscosity at the end of formulation if allowed to stand for a given period of time. A treated mud looses its treatment when the sedimentation of the clay particles occur after the treatment. Sedimentation is a sign of treatment failure. An accurate treatment of the mud (beneficiation) will enhance its quality, suitability and performance for oil well drilling application(**John Mc Dermott)**.

BENEFICIATION RESULTS

This section highlights the results(see Tables, 7.0,8.0,and 9.0)of the mud samples after beneficiation (treatment) with chemical additives such as viscosities, thinners, P^H raiser, densifier. The values obtained after each beneficiation revealed that the mud samples have attained its suitability for oil well drilling and there fore can be substituted for the commercial bentonite mud for any drilling application.

TABLE:7.0 AKOKWA MUD SAMPLE RESULTS AFTER BENEFICIATION

Mud Concen-tration	Viscometer Readings		Mud gel Strengths		Consistency Index "K"		Mud PV	Mud AV	Mud YP	Mud P^H	Mud Density	Mud Power Low Index	Mud mfv	Mud sand	Mud Temp.
(9)	(centipoise)		(Sec/Min)		(dynesec/cm^3)		(CP)	(CP)	(Ib/100ft^2)	Value	(Ib/gal)	("n")	(sec/qt)	(%)	(^{O}C)
	Ø600	Ø300	10sec	10min	@ 511	@1022									
17.5	15.9	9.6	0.1	0.3	0.62	0.33	6.6	7.6	2.5	9.0	8.70	0.75	40	0.30	25
21.1	18.5	10.4	0.3	6.2	3.0	2.04	8.2	10.2	1.8	9.0	8.72	0.56	44	0.30	25.2
24.5	28.7	18.2	0.7	11.9	1.29	0.70	12.5	13.8	4.8	9.0	8.72	0.74	45	0.30	25

Additives used:

- Drispac 1.0g
- Potash 1.0g

TABLE: 8.0 BAROID NIGERIA MUD SAMPLES RESULTS AFTER BENEFICIATION

Mud Concen-tration	Viscometer Readings		Mud gel Strengths		Consistency Index "K"		Mud PV	Mud AV	Mud YP	Mud P^H	Mud Density	Mud Power Low Index	Mud mfv	Mud sand	Mud Temp.
(g)	(centipoise)		(Sec/Min)		(dynesec/cm^3)		(CP)	(CP)	(Ib/100ft^2)	Value	(Ib/gal)	("n")	(sec/qt)	(%)	(^{O}C)
	Ø600	Ø300	10sec	10min	@ 511	@1022									
17.5	30.0	20.9	0.3	0.8	0.58	0.33	6.0	7.8	2.7	10.0	8.60	0.76	41	0.256	25.6
21.0	33.4	17.0	0.3	3.4	0.15	1.66	7.2	12.7	3.8	10.0	8.60	0.78	46	0.259	26.4
24.5	35.5	18.0	0.5	8.6	1.14	6.65	9.8	14.5	4.8	10.0	8.60	0.80	46	0.378	26.0

Additives used:

- Drispac 1.0g
- Potash 1.0g

TABLE: 9.0 AQUAGEL FOREIGN MUD SAMPLES RESULTS AFTER BENEFICIATION

Mud Concen-tration	**Viscometer Readings**		**Mud gel Strengths**		**Consistency Index "K"**		**Mud PV**	**Mud AV**	**Mud YP**	**Mud P^H**	**Mud Density**	**Mud Power Low Index**	**Mud mfv**	**Mud sand**	**Mud Temp.**
(g)	(centipoise)		(Sec/Min)		(dynesec/cm^3)		(CP)	(CP)	(Ib/100ft^2)	Value	(Ib/gal)	("n")	(sec/qt)	(%)	(^{O}C)
	Ø600	Ø300	10sec	10min	@ 511	@1022									
17.5	246.1	156.4	30.2	41.5	21.8	18.9	89.7	123.1	66.7	9.5	8.70	0.65	46	0.3	25.6
21.0	287.2	160.2	38.3	59.1	7.77	4.34	127.0	143.6	33.2	9.5	8.70	0.84	46.8	0.3	26.2
24.5	<300	179.3	above	above	above	above	above	above	above	9.5	80.70	above	49.2	0.3	26.0

Additives used:
- Drispac 1.0g
- Potash 1.0g

ANALYSIS OF RESULTS
This section details on the results of mud samples parameters before beneficiation and after beneficiation with chemical additives.

ANALYSIS OF THE RHEOLOGICAL PROPERTIES OF MUD SAMPLES
The rheological properties analyzed from the tables at Ø600 and Ø300 rpm dial readings respectively indicates that the values of the Local facilities. In the case of the foreign benetonite mud samples, the sand concentration was constant with the figure 0.30%.

ANALYSIS OF THE DENSITY OF MUD SAMPLES
The mud under the API specification ranges of 8.60 -9.60 throughout the analysis and experiments as no mud weight enhancer was employed in the experiments. However, the value of 8.50 deride from table of Baroid Nig clay was slightly below the standard specification values, with little addition of densifiers, its density was 8.701b/gal throughout the research, with or without beneficiation.

ANAYLSIS OF THE POWER LOW INDEX "n" OF MUD SAMPLE
The tables of analysis and results shows that the "n" factor of the mud samples lie between the allowable range of 0-1.0 both before and after beneficiation, and therefore makes the mud samples suitable for industrial applications and city and will in no turn yield a very high rate of penetration on application.

ANALYSIS OF THE CONSISTENCY INDEX "k" OF MUD SAMPLES
The values of "k" in the mud samples as seen from the tables of results indicates a slight difference with the standard units, but however, they are not legible enough to alter the success of drilling operation on application. The consistency index which is the shear stress determines the hole cleaning ability at lower shear rate. "K" is controlled by the type of viscosity, and solid content of the mud. "k" values increases by the reduction in the value of "n", or by an increase in the solid content of the mud. But increasing the solid content to raise the value of "k" is not recommendable because it will increase the viscosity of the bit. Increase in the value of "k" will raise the effective annular viscosity, and this will improve the hole cleaning capacity and suspension at lower shear rates(**University of Texas)**.

ANALYSIS OF THE SWELLING INDEX OF THE CLAY SAMPLES
From the table 1.0, it was observed that aqua gel bentonite clay had a very high swelling index characteristics, particularly on the 2nd, 3rd and 4th day respectively, with an additional 10ml of fresh water added into it on the three occasions, which was also lost through hydration. The local clay samples do not possess any appreciable swelling. Clay swelling properties, thus depicting settling which obviously did not make it ideal for industrial application, as its gelling properties do not conform to that of standard bentonitic clay.
Note: The gel strength of a drilling mud enables it to suspend cuttings when there is a momentary stoppage of drilling operation. However, the blend of the local clays with little

concentration of foreign aquagel bentonite clay and viscosifer thus improved the index value and the overall properties of the clay samples as shown in the tables of beneficiation.

CONCLUSION

This study shows that a beneficiated local mud sample gives a good promise for any drilling purpose at optimum clay and additives concentrations. From the conclusion and recommendation section, it has been seen that the utilization of these clays after proper beneficiation and treatment will pose no harm to surface and subsurface facilities, and will also represent a value added to the nation's economy by preventing the importation of high quality bentonite clay.

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