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(54) **QUANTIFICATION DES CARACTERISTIQUES DE DEBLAIS DE BOUES DE FORAGE COMME MESURE DE PERMEABILITE RELATIVE**

(54) **QUANTIFICATION OF DRILLING MUD CUTTINGS CHARACTERISTICS AS A MEASURE OF RELATIVE PERMEABILITY**

(57) A method is provided for establishing semi-quantitative values indicative of porosity and permeability of a formation during drilling. A sample of mud is analyzed and the proportions of each grain constituents are classified into their respective grain size divisions. Each proportion is multiplied against a corresponding weighting factor for establishing values representative of the relative contribution to the formation's porosity and when summed they establishing numeric values corresponding to an environmental index related to the porosity of the formation. Through the assignment of values for ranges of other conventional qualitative characteristics, similar and useful semi-quantitative value of relative permeability can be determined which is proportional to the environmental index, grain angularity, extent of sorting, porosity and is inversely proportional to the extent of cementation.

"QUANTIFICATION OF DRILLING MUD CUTTINGS CHARACTERISTICS AS A MEASURE OF RELATIVE PERMEABILITY"

ABSTRACT OF THE INVENTION

A method is provided for establishing semi-quantitative values indicative of porosity and permeability of a formation during drilling. A sample of mud is analyzed and the proportions of each grain constituents are classified into their respective grain size divisions. Each proportion is multiplied against a corresponding weighting factor for establishing values representative of the relative contribution to the formation's porosity and when summed they establishing numeric values corresponding to an environmental index related to the porosity of the formation. Through the assignment of values for ranges of other conventional qualitative characteristics, similar and useful semi-quantitative value of relative permeability can be determined which is proportional to the environmental index, grain angularity, extent of sorting, porosity and is inversely proportional to the extent of cementation.

QUANTIFICATION OF DRILLING MUD CUTTINGS CHARACTERISTICS AS A MEASURE OF RELATIVE PERMEABILITY

One of the challenges during drilling it to identify a zone of interest in the formation WHILE drilling. Zones of interest are usually distinguished by their permeability. Permeability is rarely determinable while drilling.

Having reference to Figs. 1 and 2, generally, we have a rig drilling a well. Drilling muds are pumped downhole through the drill string to the bit to flush any hydrocarbons and solids from around the bit. The mud flows up the annulus between the wellbore and the drilling string, to the surface for removal of solids and cuttings in an active mud system. The mud is recovered from the annulus and is passed across a shale shaker. A sample is taken at the exit of the shale shaker. A mud tank or other cleaning system (centrifuges) is used to remove finer material. Once solids are removed, mud can be reconditioned and reused.

The solids and cuttings in the mud coming up from the wellbore gives us a certain indication of what is happening downhole, and what the properties are of the formation. Additionally, a measure of the performance of the drilling gives you an additional understanding of the formation properties.

We're are reviewing the overall real-time measurements while drilling at oil wells. In the oil well situation, in the prior art, typically you would have to analyse this after the fact to determine whether or not yet useful information has been obtained or not.

Alone, many of these indicators are insufficient to categorically state that the well has been drilled into or through a zone of interest. Combined together, the independent factors could be enough.

Typically, a sample of the mud is obtained once for every 5 meters depth of drilling. The mud and extreme fines are washed of the liquid carrier, leaving the solids.

The solids are typically analysed for their characteristics by visually assessing the solids according to industry standards.

Such characteristics include grain size, angularity, sorting, cementation and porosity

These characteristics are usually identified on well logs co-ordinated with the depth and lithology of the sample.
Using the above characteristics, a method is provided herein which represents a the quantitative measure for the above rather than merely providing a qualitative assessment.

The qualitative assessment assists in numerically assessing the porority if a formation while drilling. Porosity is one factor of estimating permeability of a formation.

Porosity is indicated in one of several ways including the above characteristics and drilling performance.

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Quantitiative values are already obtained by observing drilling performance. Performance is measured in several ways including force on the bit FOB and bit rpm, measured at the doghouse by the driller.

Many factors may be applied, some of which are based on previous drilling experience such as was experienced in adjacent wells or similar formations. Rpm, mud type, mud weight, and previous knowledge of the formations expected. For example, if you know already that you have sandstone, limestone, or Dolomite at different levels, you may change the bit rpm; say 50 rpm at limestone or 60 at Dolomite.

Additionally you will have rate of penetration ROP; if you're really cutting quickly then you know you are cutting something fairly soft or porous (could be the same thing).

With respect to the actual composition of the formation, we have the mud coming out which gives us indication of certain factors, the type formation, and the gases available. Note that the mud being measured is associated with a lag time. This means that the mud at the surface is indicative of what was drilled sometime earlier because of the time necessary to flow the mud to the surface from the bit.

The method of the invention involves conversion of qualitative ratings into quantitative indexes and then applying the indexes to establish a relative quantitative measure of the permeability.

A permeability index is found to be proportional to the grain size the square of the angularity, the square of the solids sorting, and the inverse of the square of the cementation.

More particularly:

Grain Size - Environmental Index (EnvNdx)

The grain size of solids and cuttings are rated as very fine through very coarse.

Having reference to Fig. 3, in the prior art, a geologist inspects the washed solids and grades the solids as ranging between 5 ranges grain sizes:

- Very-Fine 0.004 – 0.0625 mm
- Fine 0.0625 - .125 mm
- Medium 0.125 – 0.250 mm
- Coarse 0.250 – 0.500 mm
- Very-Coarse 0.500 – 1.000 mm

(under some standards the 5 step grains size is labelled as Silt, Very Fine, Fine, Medium and Coarse)

This is a qualitative analysis. The geologist may classify a sample containing a small amount of Very Fine and mostly coarse as M (medium) or C (coarse) or M-C.

Subsequently, the presence of the Very-Fine material is lost when another reviews the geologist report of "M-C". In fact, the presence of the V-F material could have a significant effect, or significantly reflect, the porosity and permeability of the formation from which those cuttings came.

Environmental Index is only one indication of the nature of the formation. This can represent a hypothetical "distance from Source", i.e. closer to the "source", the rock is coarse, further away is very fine.

There are several things we can determine we look the mud coming up an analysis of the cutting will give us the environmental index, giving us very fine, fine, medium, coarse, very coarse (VF,F,M,C,VC). Prospectors has set up the system to quantify the coarseness of the cuttings.

This is done by setting up five regions reflective of (VF,F,M,C,VC), and assigning a value for the fraction of each type of solids in each of those regions, the total across all regions and being 10. Then we assign a weighting factor for each region. The weighting factor for very fine is 1, the weighting factor for very coarse is 5. The weighting factors therefore are 1 through 5 for regions 1 through 5.

Now one can quantify the type of cuttings by a number such as 36, rather than saying that it is merely coarse. For example one might assign values for the regions as 0|2|0|8|0. By applying the weighting factors one multiplies 2 by 2, and multiply 8 by 4, for total of 36, whereas previously a geologist might have seen the predominant coarse material and merely labelled this material as coarse.

	VF	F	M	C	VC		
value	0	2	0	8	0		
weight	1	2	3	4	5		
	0	4	0	32	0	=	36

	VF	F	M	C	VC		
value	5	2	0	3	0		
weight	1	2	3	4	5		
	5	4	0	12	0	=	21

	VF	F	M	C	VC		
value	8	2	0	0	0		
weight	1	2	3	4	5		
	8	4	0	0	0	=	12

Having reference to Fig. 4, in a case where a vug (a small cavity in rock lined with crystals) is drilled through, if the geologist missed the fact that some of the solids were in fact crystals, the presence of substantially fine crystals would lead the geologist to assess the porosity and potential permeability as low, when in fact the crystals are indicative of higher porosity.

The Environmental index would weights the presence of the coarser solids higher and would quantify the porosity of the overall sample as higher, more representative of the true porosity.

By applying the lag time one can associate the type of material with a drilling depth. By providing a quantitative analysis of the solids returned with the mud, a better analysis can be performed of an estimate of the porosity of the formation – a large factor in assessing the potential of a particular formation of produce.

Angularity Index (AngNdx)

Angularity is rated as:

A – for angular (many sharp and pronounced protrusions)
a – for subsangular (many protrusions but they are somewhat rounded)
r – for subrounded (rounded protrusions which are less pronounced)
R – rounded

A value of 1 – 4 is applied to A,a,r,R respectively.

Sorting Index (SrtNdx)

Sorting is defined as:

W – well (1 or 2 sizegrades)
M – medium (3 or 4 sizegrades)
P – poor (5 or more sizegrades)

A value of 1 – 3 is applied to W,M,P respectively.

Cementation Index (CemNdx)

Cementation is defined as the degree of binding together of the grains:

cm-1 slightly (<10%)
cm-2 slightly (10-20%)
cm-3 slightly (20-30%)
cm-4 slightly (30-40%)
cm-5 slightly (>40%)

A value of 1 – 5 is applied to cm-1, cm-2, cm-3, cm-4, cm-5 respectively.

Porosity (Por)

Usually porosity is graded on a 0 – 20% scale. For the purposes of quantifying a permeability index, the range is expanded to 0 - 40%.

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Permeability index (PermNdx)

As a general indication of permeability, one can quickly calculate an Environmental Index.

If the geological quality assessments are available, a more comprehensive assessment of the relative permeability can be determined from the following

$$PermNdx = \frac{EnvNdx * (AngNdx)^2 * (SrtNdx)^2}{(CemNdx)^2} * Por$$

So, for example, with an Environmental Index of 36, an Angularity Index for a subrounded particle (r) of 3, a Sorting Index for medium sorted material of 2, a porosity of 10% and a Cementation Index of moderate at 3, then the permeability index, as a relative quantitative measure of permeability is:

$$PermNdx = \frac{36 * (3)^2 * (2)^2}{(3)^2} * 10 = 1440$$

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THE EMBODIMENTS OF THE INVENTION FOR WHICH AND EXCLUSIVE PROPERTY OR PRIVILEGE ARE DEFINED AS FOLLOWS:

1. A method of quantitating relative porosity of a drilled formation from cuttings having constituents which are capable of being graded corresponding to a plurality of discrete grain size divisions comprising the steps of:

(a) assigning numerical weighting factors to each of the discrete grain size divisions, the value of the weighting factor being correspondingly greater the larger the grain size in the division;

(b) classifying the proportions of the cuttings constituents between the discrete grain size divisions;

(c) multiplying the classified proportions by the corresponding weighting factor for establishing values representative of the relative contribution to the formation's porosity; and

(d) summing the relative contributions for each grain size division for establishing numeric values corresponding to the porosity of the formation.

2. The method as recited in claim 1 wherein when the relative size of grains in each larger division are substantially double those of the smaller division then the increase in the corresponding values of the weighting factors is linear.

3. The method as recited in claim 2 wherein grain sizes are classified in five divisions, the value of the classified proportion of each constituent is determined on a scale of 1 to 10 and wherein the corresponding weighting factors have values of 1 – 5 respectively.

4. The method as recited in claim 3 wherein grain sizes are classified into five divisions having constituent sizes of up to 0.0625 mm, 0.125, 0.25, 0.5 and 1 mm respectively.

5. A method of quantitating relative permeability of a drilled formation from cuttings comprising the steps of:

(a) assigning numerical values for the proportion grains in each of a plurality of grain size divisions within a sample and a weighting factor for each division corresponding thereto for establishing a environmental index value EnviroNdx;

(b) assigning a numerical value to the degree of angularity of grains within a sample for establishing an angularity index value AngNdx;

(c) assigning a numerical value to the degree to which the grains within a sample are the same for establishing a sorting index value SrtNdx;

(d) assigning a numerical value to the degree to which the grains within a sample bind together for establishing a cementation index value CemNdx;

(e) assigning a numerical value to the degree of porosity of the sample for establishing a porosity value Por; and

(f) determining the relative permeability index PermNdx of the sample as being substantially proportional to EnvNdx, AngNd, SrtNdx and Por and inversely proportional to CemNdx.

6. The method as recited in claim 5 wherein the relative permeability index PermNdx of the sample is established using the relationship:

$$PermNdx = \frac{EnvNdx \times (AngNdx)^2 \times (Srt\ Ndx)^2}{(CemNdx)^2} \times Por$$

7. A system for establishing the relative porosity of a drilled formation from cuttings during drilling comprising the steps of:

(a) obtaining a sample of cuttings corresponding to the formation;

(b) classifying the proportions of the cuttings constituents between a plurality of discrete grain size divisions;

(c) assigning numerical weighting factors to each of the discrete grain size divisions, the value of the weighting factor being correspondingly greater the larger the grain size in the division;

(d) multiplying the classified proportions by the corresponding weighting factor for establishing values representative of the relative contribution to the formation's porosity; and

(e) summing the relative contributions for each grain size division for establishing numeric values corresponding to the porosity of the formation.

FIG. 1.

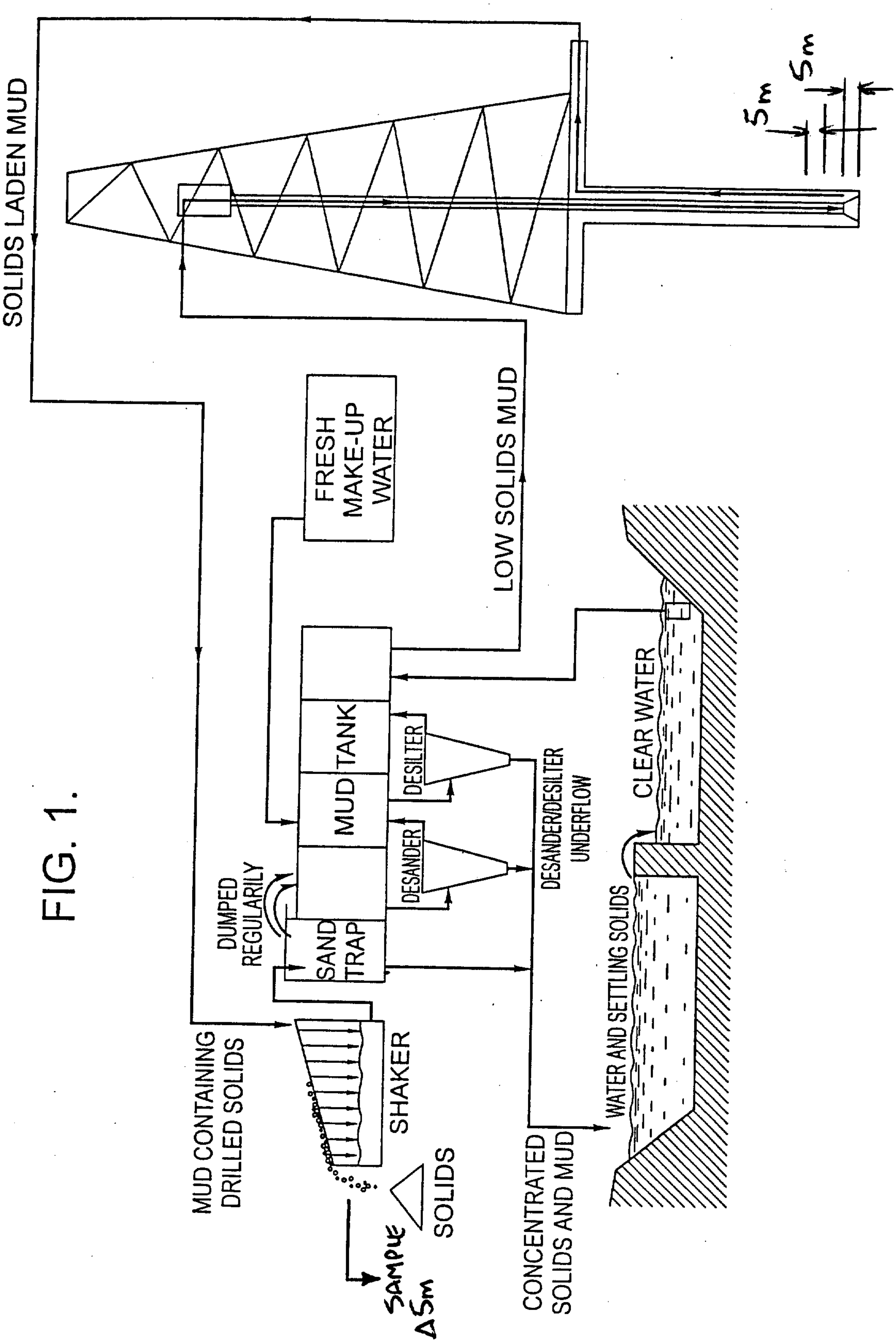
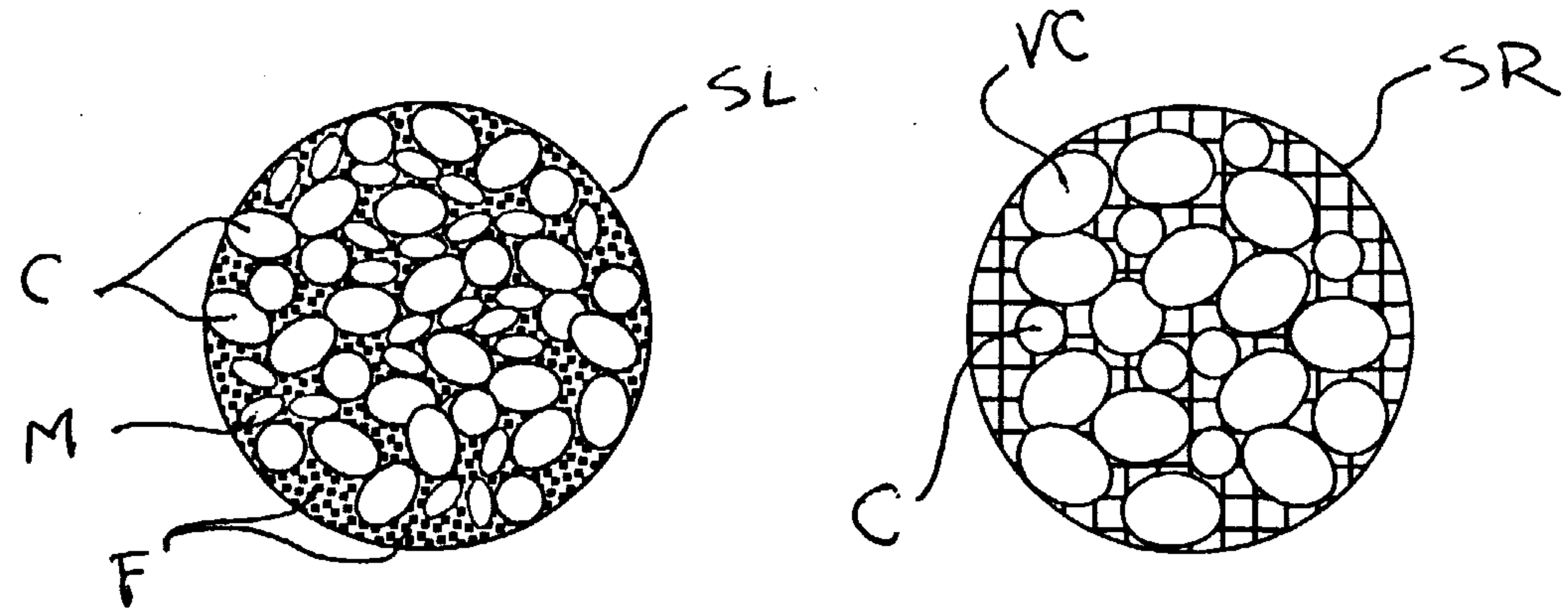

SOLIDS LADEN MUD
LOW SOLIDS MUD
FRESH MAKE-UP WATER
MUD TANK
SAND TRAP
DUMPED REGULARILY
DESANDER
DESILTER
DESANDER/DESILTER UNDERFLOW
CLEAR WATER
WATER AND SETTLING SOLIDS
CONCENTRATED SOLIDS AND MUD
MUD CONTAINING DRILLED SOLIDS
SHAKER
SOLIDS
SAMPLE
Δ5m
5m
5m

Fig. 2



Qualitative
(Prior Art)

Medium **M**

Coarse **C**

Environmental Index

23

42

	VF	F	M	C	VC	
Grain Grade	1	6	2	1	0	10
Weighing	1	2	3	4	5	
Env. Index	1	12	6	4	0	23

F1

	VF	F	M	C	VC	
Grain Grade	0	0	0	8	2	10
Weighing	1	2	3	4	5	
Env. Index	0	0	0	32	10	42

F2