SHALE GAS -
An Alternate Energy Source, its resource in India, world examples, Production & Technology.

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SHALE GAS

Shale gas refers to natural gas (mainly methane) found in fine-grained, organic-rich rocks (gas shales). This is the gas that never left the mother rock where it was formed. For the time being, only Northern America - and mostly US - has been explored for this kind of resource, and very large amounts of "gas in place" have been found.It can also happen that gas has been created in significant amounts in the mother rock, but then... migrated and is not there anymore! For all these reasons, it is almost impossible to know what the proportion of gas in the mother rock is without drilling a number of exploration wells.

Even when the proportion of gas is significant, Shales are compact rocks with low permeability, which also hinders an easy circulation of the gas in the rock.

As a result, the recoverable amounts of shale gas are calculated by multiplying figures close to ∞ (gas in place) by something close to 0 (extraction ratio), which makes it difficult to calculate reserves.

Shale Gas is one of the unconventional gas resources, hence brief notes of the unconventional gas resources are mentioned below.

NON CONVENTIONAL GAS RESOURCES

Non conventional gas is any gas that is something else than... conventional gas! Conventional gas corresponds to gas that has followed an "ordinary path" regarding its origin. It was formed in a mother rock, migrated, and accumulated in a reservoir rock where it can be associated with oil and water.

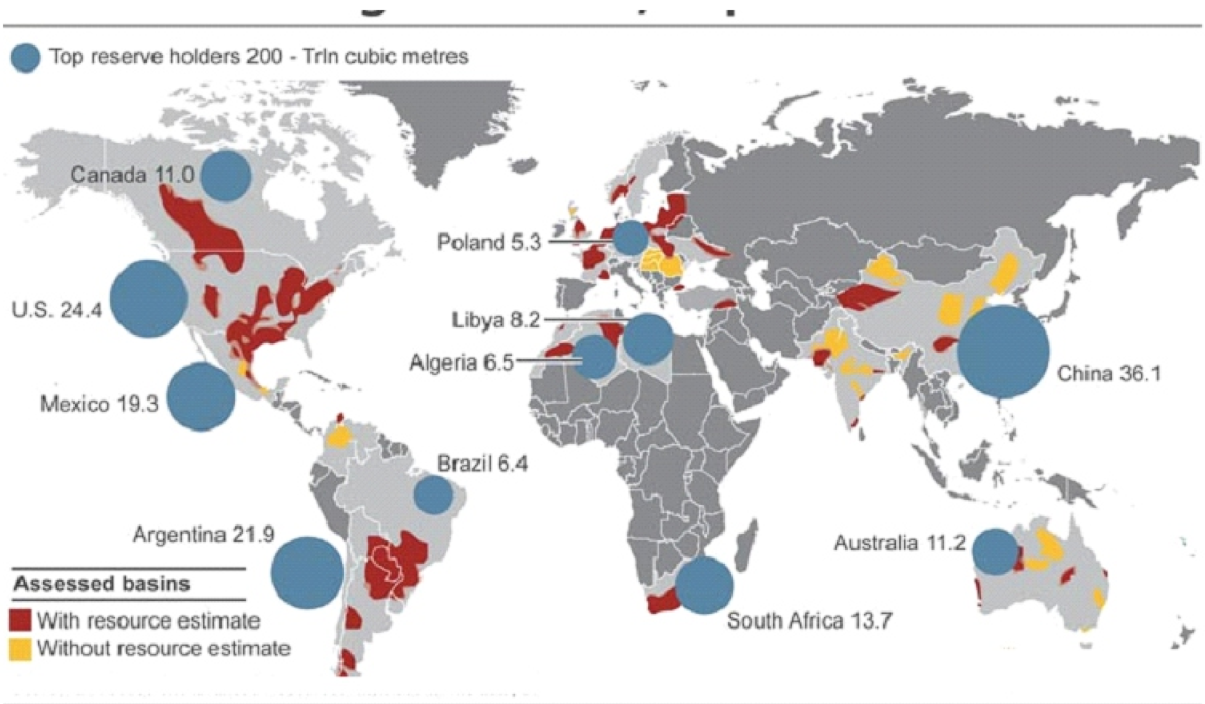
As non conventional gas is by definition "anything which is not conventional gas", it aggregates very different geological objects, that only have in common to hold a little gas, generally not very mobile and not as easy to produce as conventional gas.

Non – conventional gases include Shale Gas, Coal Bed Methane or Coal Seam Methane, Tight Gas, Gas Hydrates etc.
Shale Gas is the gas that remained in the mother rock i.e. Shale where it was formed.
Coal Bed Methane or Coal Seam Methane is the gas that remained in the coal seam where it was formed.
Gas Hydrates are the gases associated with lot of water; they also include the gas produced in the Polar Regions.

WORLD POTENTIAL – BUSINESS - TECHNOLOGY

Although shale gas has been produced for more than 100 years in the Appalachian Basin and the Illinois Basin of the United States, the wells were often marginally economical. Higher natural-gas prices in recent years and advances in hydraulic fracturing and horizontal completions have made shale-gas wells more profitable.As of June 2011, the validity of the claims of economic viability of these wells has begun to be publicly questioned.Shale gas tends to cost more to produce than gas from conventional wells, because of the expense of the massive hydraulic fracturing treatments required to produce shale gas, and of horizontal drilling.Total published estimates for UK shale gas resources by companies holding shale gas estimated that only around 10-15% of this is recoverable and can therefore be treated as reserves.

However, a June, 2011 New York Times investigation of industrial emails and internal documents found that the financial benefits of unconventional shale gas extraction in USA imported 840 Bcf out of which785is from Canada while exporting 400 Bcf mostly to Canada; both mainly by pipeline.Almost none is exported by ship as LNG, as that would require expensive facilities. Prices have gone down to $3/MMBtu due to shale gas. The major shale gas basins are shown in the following figure.

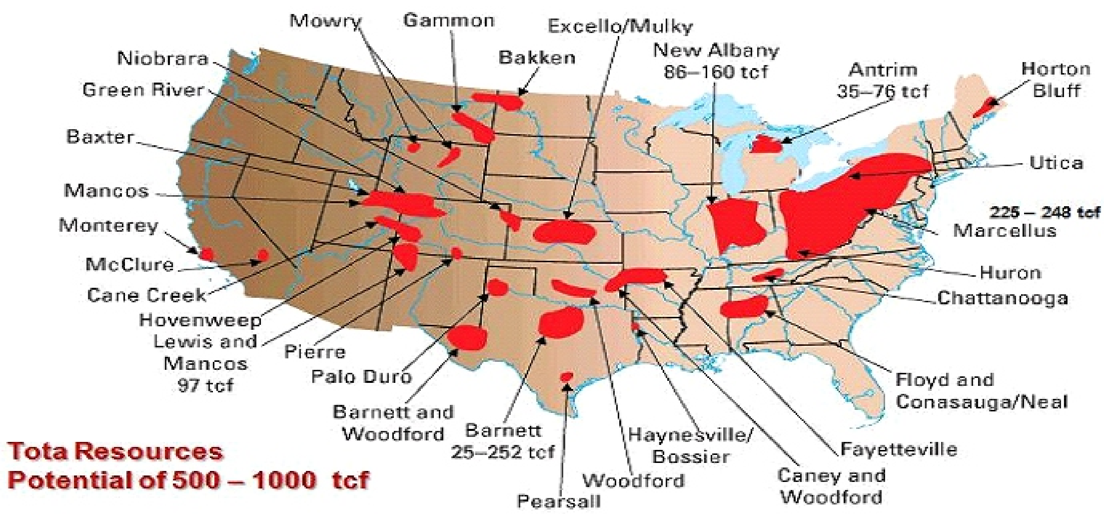


GENESIS

'Black shales' are dark, as a result of being especially rich in unoxidizedcarbon. Common in some Paleozoic and Mesozoicstrata, black shales were deposited in anoxic, reducing environments, such as in stagnant water columns. Some black shales contain abundant heavy metals such as molybdenum, uranium, vanadium, and zinc.

There are two theories as to how natural gas is formed. The most widely accepted theory, the organic theory, maintains that natural gas formation begins with photosynthesis, where plants use energy from the sun to convert carbon dioxide and water into oxygen and carbohydrates.

The remains of these plants and the animal forms that consume them are buried by sediment and as the sediment load increases, heat and pressure from burial converts the carbohydrates into hydrocarbons. Natural gas formation takes place in fine-grained, black, organic, shale source rocks. Continued pressure from burial forces most of the natural gas to migrate from the organic shales into more porous and permeable rock such as sandstone and limestone. The natural gas remaining in the shales is termed shale gas.



E&P companies have routinely produced hydrocarbons from shale. For instance, operators in Brazil, Estonia, Germany, and China produce oil from shales by retorting however, as of 2011 there were no commercial operations producing gas from shales outside North America.

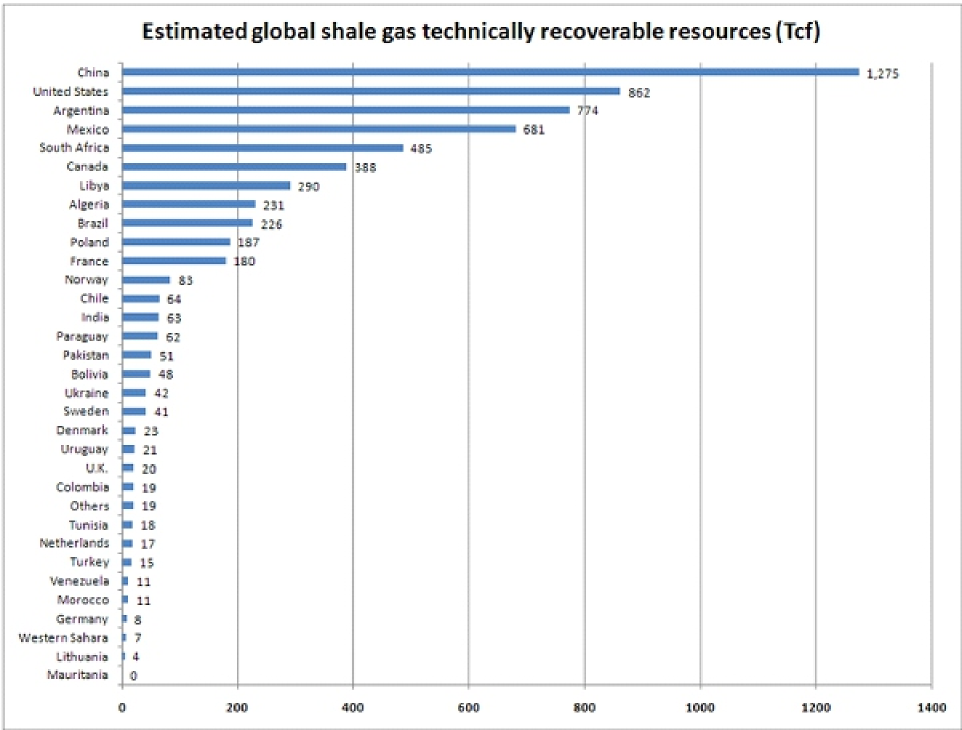
That situation may change rapidly. Gas shale exploration is outgoing in South America, Africa, Australia, Europe and Asia.

Shale gas basins of America

Unlike shale development in US, where smaller operators were instrumental in much of the activity, European gas shale exploration and development tend to be dominated by large multinational energy companies and national oil companies. Companies with substantial acreage positions in Europe include ExxonMobil Corporation, Total S.A, conocol Phillips Company and Marthon Company.

Region	1997 Rogner Study, Tcf	2011 EIA Study, tcf
North America	3842	7140
South America	2117	4569
Europe	549	2587
Africa	1548	3962
Asia	3528	5661
Ausralia	2313	1381
Other	2215	Not available
Total	16,112	25,300

Shale gas estimation of various countries – 1997 and 2011



GENERAL STRTIGRAPHY OF INDIA

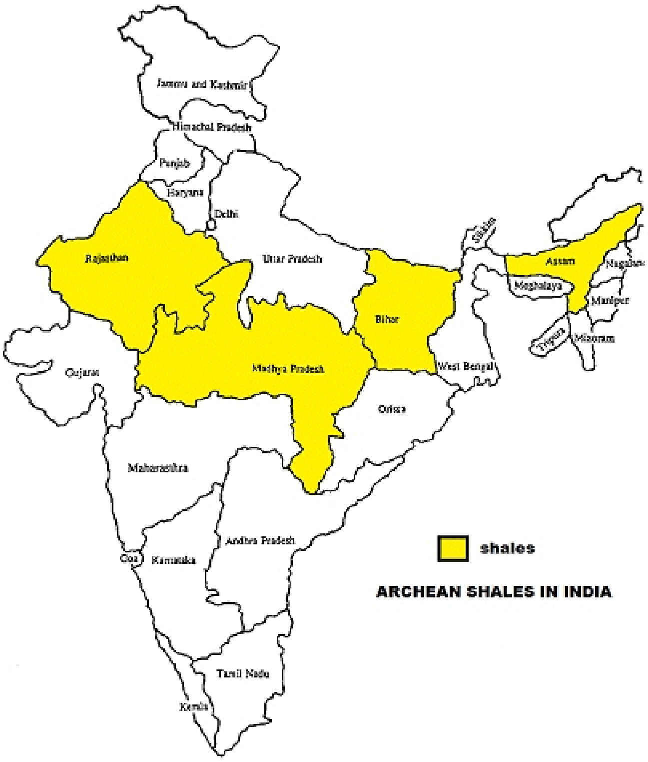
More than half of the Peninsula is occupied by gneissic and schistose rocks of the Archean and Proterozoic ages. The Cuddapahs, Vindhyans, the Gondwanas and the Deccan Traps occupy the rest of the area, except parts of the coastal regions. In the Extra-Peninsula, marine sedimentary systems predominate, though parts of the sub-Himalaya and the main axis of the Himalaya are occupied by ancient metamorphic rocks and intrusive igneous rocks. A full succession of fossiliferous sedimentary systems, extending from the Cambrian to Eocene, is met with on the Tibetan side of the Himalaya, while the southern or Sub-Himalayan zone contains a different facies which is practically unfossiliferous. The fossiliferous facies transgresses to the south of the central Himalayan zone in Kashmir

STRATIGRAPHY OF INDIAN SHALES

Binota Shales

An unmetamorphosed facies of the Aravallis occurs in Eastern Mewar east of Great Boundary Fault of Rajasthan. This has been named the Binota Shales and consists of low dipping, brown and olive shales with ferruginous and clay concretions.

In the east, the Binota Shales are succeded by the Jiran Sandstones, Vindhyans or the Deccan trap. To the west of the Boundary Fault, the Aravallis are represented by steep dipping slates and impure limestone intruded by dolerite. Followed westwards, these shales become first distinctly slaty or phyllitic, and later schistose, with the development of staurolite, garnet and kyanite.



Nandyal Shales and Auk Shales

The cuddapah basin in the Andhra state contains two areas of younger rocks resting unconformably on the cuddapas – one in the Kundair Valley stretching up to the Krishna, and the other in the Palnad tract. This younger group of rocks, constituting the Kurnool System is about 400m thick in the west but much thicker in the Palnad area and has been affected by disturbances in the eastern part but by forces which were less intense than those which acted on the Cuddapahs. This system is regarded as the equivalent of the Lower Vindhyans.

Auk shale.

TRIASSIC

Two major facies of the Triassic are developed in Europe. The Germanic facies occurring in Germany and the British Isles is partly continental and partly epicontinental marine, while the Mediterranean facies is geosynclinals and is found in the Alps, Pyrenees and North Africa.

In the Salt-Range the Triassic system is confined to the Lower Trias and the lower part of the Upper Triassic stages only. In the two latter areas it assumes an argillaceous facies of shales and slates, whereas in Himalayan region the system is entirely composed of limestone, dolomites and calcareous shales.
Shales of the Triasssic age are as follows.

Dark shales

The rocks of this system are found in Prome and Thayetmyo districts, usually much folder and disturbed. They consist of dark shales and sandstones with some limestones. The only fossils found in them are Daonella lommeli and specimens of Monotis and Avicula. These seem to indicate a Triassic age. Farther south in Minbu and Pakokku districts, the equivalents of the Lower Axial are Chin Shales.

Daonella Shales and Grey Shales

The upper Muschelkalk bed shows a gradual passage to the Ladinic stage, they begin no noticeable change in the stratigraphical unit; that is to say, the Ladinic begins somewhere in the Daonella shales, about 50m thick, consisting of shaly limestones and shales. The Daonella shales enclose a typical Ladinic fauna amongst which may be mentioned: Daonella lommeli, D. Indica, Spirigera hunica,

Kuti Shales

The Kuti Shales which have a sharp boundary with the Kalapani Limestones, are micaceous shales with calcareous flags, 100 to 500 m thick. Fossils are generally rare in the Kuti Shales but an excellent collection has been obtained on Tinkar Lipu from the black shales and the intercalated calcareous flags. These included Halorires cf. procyon, Thetidites huxleyi,s

Monotis Shale

Flaggy limestones and sandy shales, which attain a thickness of 100m. The sandy shales and sandstones especially contain abundant fossils.

JURASSIC
Alum Shales and Shales with Belemnites

The middle and upper divisions of the Jurassic system are developed in the western portion of the salt range and in the Trans-Indus region as a series of sandstones and limestones, the latter increasing in proportion west ward. The strata are 30 to 60 m thick near Amb, 150m near kalabagh on the Indus and over 600m in the sheik budin hills and surghar range. The facies in dominantly coastal and generally resembles that of kutch in western india.


A *Dactylioceras* body chamber in situ in the Alum Shale.

Alum shale Belemnite Spiti Shales

The beds succeeding the Triassic Kioto Limestones are the Spiti Shales which extend from Upper Oxfordian to Lower Neocomian, a part of the Kimeridgian being probably unrepresented. The type section is in spiti but they are developed over a considerable length of the Himalayas from beyond the Kanchenjunga in the east.

They are generally 30 to 40 m thick consisting of micaceous shales with several intercalated layers of sandstones each of the latter being only a few centimetres thick.

CRETACEOUS

The Cretaceous is largely marine in most places though a continental facies of the Lower Cretaceous with plant fossils and reptiles, fishes etc. is also found in some regions, especially in Gondwanaland. There are two distinct marine facies in Europe, one being that of N.W. Europe with characteristic chalk deposits.
Shales of the Cretaceous age are as follows.

Belemnite Shales

The Belemnite Shales extend into the Cenomanian only in the Sulaiman Range. In the more southern areas the Parh limestones commence in the Upper Albian and continue through to the Campanian.

The Pab Sandstone succeeds the Nishapa Formation or the Orbitoid Limestone, as the case maybe. In the north there is disconformity reak in between it and the succeeding Dunghan Shales of Palaeocene age, while in the south the sedimentation is continuous and does not show a break. The orbitoid Limestone corresponds to the Hemipneustes Beds. The Stratigraphic position of Belemnite Shales is shown in the following stratigraphic succession.

Raghavapuram Shales

Arenaceous shale

The Upper Gondwanas are found between Rajamundry and Vijayawada, resting unconformably upon the Kamthi i.e. Chintalpudi sandstones. They comprise three divisions, the Golapalli Sandstones below, Ragavapuram Shales and the Tirupati sandstones above. The lower division comprises about 350 feet of orange to brown Sandstone and Grits, enclosing the flora allied to the Rajamahal. The Ragavapuram Shales which succeed them consist of 150 feet of white and buff shales, sometimes variegated, and purplish arenaceous shales. They contain plants as well as marine fauna like Cephalopods and Molluscs.

EOCENE

In India the Eocene begins with the Ranikot stage i.e. Lower Eocene which is developed in Sind and farther north. The overlying Laki and Kirthar stages i.e. Middle to Upper Eocene are developed much more extensively in the northwestern India.

Dzong buk Shales

Eocene rocks are found in the Upper Indus valley in Ladakh along a zone parallel to the Himalayan axis from Kargil to Leh, Hanle and beyond. They consist of feldspathic grits, green and purple shales known as Dzong buk Shales and limestones containing badly preserved Nummules and other fossils.

The rocks have been subjected to folding and crushing and igneous intrusions on a large scale. From fossil evidence it is known that the sidiments extend in age from the Cretaceous to Oligocene.

POSSIBILITIES FOR SHALE GAS IN INDIA

The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of State, is assessing the potential for unconventional oil and gas resources like shale gas, shale oil, tight gas and coal bed gas in priority geologic provinces worldwide.

This report summarizes the geologic model and assessment of potential shale gas resources of the Bombay, Cauvery and Krishna–Godavari Provinces of Indian subcontinent.

These geologic provinces are located along the margins of the Indian subcontinent and contain the basins that were assessed in this study.

The basins are interpreted to have originated as rift or sag basins and they control the distribution of Mesozoic and Cenozoic source rocks as well as the shale gas resources in the respective geologic provinces.

Cambay Basin

The upper Palaeocene to middle Eocene Cambay Shale is interpreted to be a major source rock in the Cambay Basin as said by the Directorate General of Hydrocarbons, Cambay Basin, written commun., 2009.

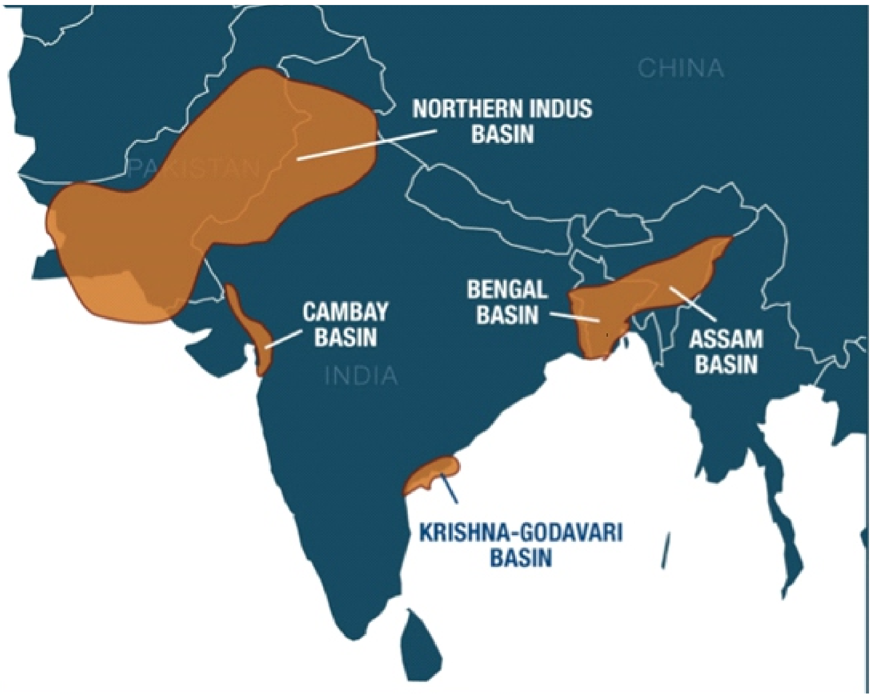
Cambay Shale was deposited in deltaic and near shore marine environments in the northern and central parts of the basin, and in deeper marine environments in the southern part of the basin.

Therefore, this source rock presumably contains greater amounts of type II kerogen southward in the basin. Thermal maturity increases from north to south across the basin. Although the Cambay Shale is in the oil-generation window in the north, it is in the gas-generation window in the south.

At the base of the shale, vitrinite reflectance values are greater than 1.1 percent. Total organic carbon contents i.e. TOC are greatest in the basin depocenters, with concentrations greater than 4 weight percent.

Cauvery Basin

Potential source rocks in the Cauvery Basin include shales of the Lower Cretaceous Andimadam Formation and the Lower to Upper Cretaceous Sattapadi Shale and its stratigraphic equivalents as stated by the Directorate General of Hydrocarbons, Cauvery Basin, written commun., 2009. The shales are interpreted to have been deposited in marine environments. The Sattapadi Shale contains 2 to 2.5 weight percent of TOC and is thermally mature for hydrocarbon generation in deeper parts of the basin.
Ro values vary from approximately 1.0 percent to as much as approximately 1.5 percent. Kerogen types are predominantly type III with minor amounts of type II.



Krishna–Godavari Basin

The Upper Jurassic to Cretaceous Raghavapuram Shale and its stratigraphic equivalents are inferred to be the main source rock for much of the Krishna–Godavari Basin as stated by the Directorate General of Hydrocarbons, Krishna–Godavari Basin, written commun., 2009. The Raghavapuram Shale was deposited in marginal marine to inner shelf environments, whereas the stratigraphically equivalent Chintalapalli Shale accumulated under bathyal conditions. The shale contains as much as 2.4 weight percent TOC, and its thermal maturity ranges from immature to mature with respect to gas generation. Type III kerogen is most common, but type II is present where the shale was deposited under deeper marine conditions.

Shale gas basins of India

Basing on the above information the shale gas assessment in India from Bombay, Cauvery and Krishna-Godavari basins was done by Geologic Model of assessment as stated below.

Geologic Model for Assessment

The geologic model that forms the basis for the assessment of Bombay, Cauvery, and Krishna–Godavari Provinces is that the shales are self-sourced. Gas was generated in Mesozoic and Cenozoic organic-rich shales and filled matrix and organic matter porosity in the same shales. Evaluations for each of the shale gas systems and areas to be assessed used five criteria: (1) average TOC of 2 weight percent or greater; (2) presence of type I, II, or III kerogens; (3) thermal maturity equivalent to at least 1.1 percent Ro; (4) presence of thermogenic gas; and (5) net source rock thickness of 15 meters or more. All five of these criteria must be present at one place to continue with an assessment as given by Charpentier and Cook in the year 2011.

SHALE GAS PRODUCTION TECHNOLOGY

Hydraulic fracturing

Hydraulic fracturing involves pumping large volumes of fluid through perforations and into the formation at rates and pressures sufficient to not only create a fracture, but also propagate it far beyond the near-wellbore region. The final fluidstage fills the fracture with proppant—silicate,ceramic or bauxite granules with high sphericity—leaving a high-permeability conduit between theproducing formation and the wellbore.

Exploration considerations:

The below mentioned factors are some of the exploration considerations.

- Natural fractures – friends or foe 2) Facies changes – greater permeability 3)Kerogen type - I II IIS III. 4) Microbial or thermogenic gas.5) Thermal maturation history.5) MWD especially gas isotopes.

To start the production in a shale rock some elements must be consider for successful shale gas exploration, they are

- Thickness of reservoir.

2) Organic richness
3) Maturation of organic matter
4) Gas – in – place (formation).
5) Mineralogy
6) Brittleness
7) Pore pressure
8) Permeability.

Fracturing fluid:

Fracturing fulid contain mainly water, sand, some chemical additives, the percentage of contents in the mixture are given mentioned. Water – 90%, Sand – 9.5%, the chemical additives are mainly (Sodium chloride, Ethylene glycol, Borate salt, Sodium/Potassium carbonate, Gour gum ,Isopropanol.) – 0.5%.

Fracturing-fluid viscosity is a critical parameter that governs fracture initiation and propagation, as well as proppant transport down the tubulars, through perforations and into the fracture At suitable conditions, sufficient fluid viscosity is usually achieved by preparing meta crosslinked solutions of guar-base polymers.

Mechanism:

Fracturing in rocks at depth tends to be suppressed by the confining pressure, due to the load caused by the overlying rock strata. Hydraulic fracturing occurs when the effective stress is reduced sufficiently by an increase in the pressure of fluids within the rock, such that the minimum principal stress becomes tensile and exceeds the tensile strength of the material.

Fractures formed in this way will be oriented in the plane perpendicular to the minimum principal stress and for this reason induced hydraulic fractures in wellbores are sometimes used to determine the orientation of stresses.

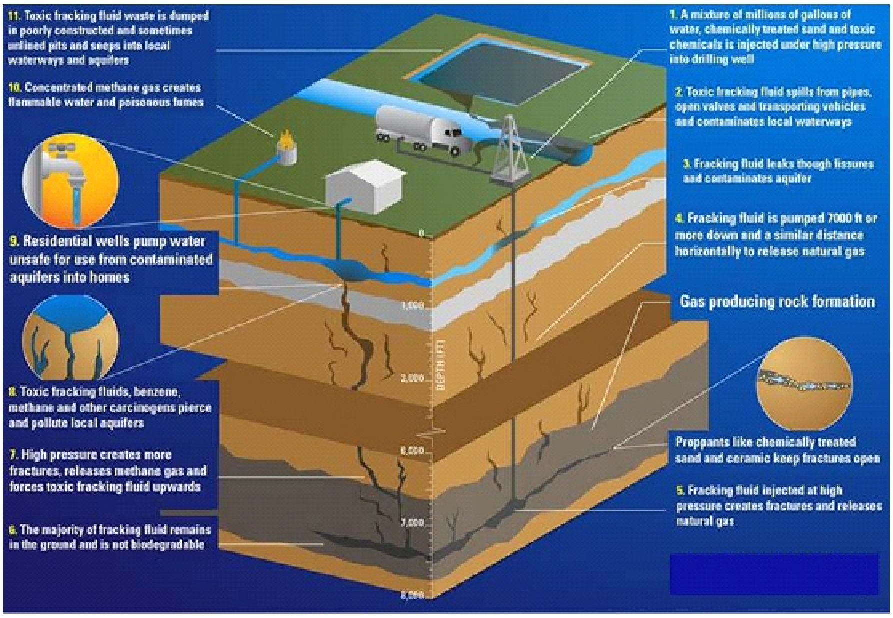


Diagram showing the shale gas production

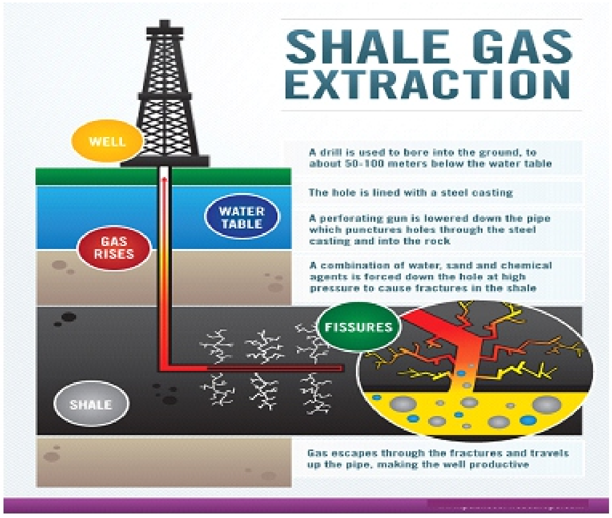
The most common metal crosslinkers are boron and zirconium. However, viscosity attainment alone is not sufficient to perform a successful fracturing treatment To minimize friction pressure losses as the fluid is pumped downhole the crosslinking reactions should be delayed until just before the fluid enters the perforations.

In addition, the viscosity should not be unduly sensitive to the high-shear-rate environment commonly found in the tubulars and perfora tions otherwise, the fluid will be ill equipped for fracture propagation and proppant transport, increasing the likelihood of a premature screenout.

The characteristics of borate- and zirconate crosslinked fluids are fundamentally different.Borate crosslinking arises from ionic bonds that can break under high-shear conditions; however,the bonds heal and fluid viscosity recovers when a low-shear environment is restored Zirconate crosslinked fluids are not as forgiving because the linkage results from covalent bonds that form only once.

If the fluid crosslinks and experiences elevated shear too early, the bonds will break irreversibly, fluid viscosity will decrease, and the screenout probability will increase (below).

Therefore, it is vital to control the timing and the location of crosslinking Although less forgiving, zirconatecrosslinked fluids have been used almost exclusively in fracturing treatments, mainly because they are thermally more stable than borate fluids.



Shale factor: Shale factor analysis is also utilized for over pressure detection. It is a simplified well site determination of the mineral constitutes in the rocks. It is also known as methylene blue test. Usually the shale factor may be equated with the caion exchange capacity than other clays. An increase in the montimorillonite clays will mean lighter density shale which could mean that it could be interpreted as under compacted shale. Several authors have associated montimorilonite with deep marine shales in which sands are absent. During the process of diagenesis, montimorilonite is converted to mixed layer and illite clays. Hence montimorilonite decreases with depth. Montimorilonite/illite ratio in the sample is measured as the cation exchange capacity in milliequivalents per 100gms of sample and termed as shale factor.

CONCLUSIONS:

Shale gas was not considered as a resource till the last century, all over the world. But with the beginning of the 21st century, shale gas emerged as an unconventional resource along with tight gas, gas hydrates and coal bed methane. "India is rich in shales and thus may be source of shale gas which is the future energy resource with more advancement in technology."

The Krishna-Godavari basin could soon become the new source of shale gas, which promises to provide energy for the next 200 years. The KG basin is one of the few places identified in India for the exploitation of shale gas. The potential deposits of shale gas in the country have been estimated at between 600 and 2,000 trillion cubic meters.

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