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Proppant Management – A New Challenge to Develop Unconventional Reservoirs in Argentina

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Agenda

- Introduction
- Reservoir Conditions for Proppant Selection
- Proppant Type and Stimulation
    - *Shale and Tight formations*
- Logistic and Supply Chain
    - *Traditional and New Model for Proppant supply chain*
    - *Case History*
- Laboratory Test for Local White Sand
- Discussion and Conclusions

Introduction

- Argentina History
  - *1st Hydraulic Fracturing (1960) - Conventional and Uncoventional Reservoirs*
  - *Several types of proppant (white sand, RCP, Ceramic) and mesh proppant (8/12, 12/20, 16/30, 20/40, 30/50, 40/70, and 70/140 (nominally 100 mesh)*
- Origin of proppant (USA and Brazil) and Studies of local sands (1980s)
- Unconventional reservoirs (Tight-2001 and shale 2010)
  - *More consuption and new mesh proppant (50/150, 70/140, 40/70, and 30/50)*
- USA experience documented using white sand in Unconventional and non-API proppant

Reservoir Conditions for Proppant Selection

- Strength of the proppant grains is of major concern in the design of propped fractures
  - ***Closure Stress on proppant = Min-Hztal Stress – BHFP (ResPress*0.7)***

Basin	Reservoir	Formation	Depth (ft)	BH Temp. (°F)	Min-Hzt Stress (psi)	Res. Pressure (psi)
Neuquén	Shale	Agrio	10,950	224	10,868	8,020
Neuquén	Shale	Vaca Muerta	7,550 - 10,950	175 - 225	6,300 - 10,400	5,600 - 9,600
Neuquén	Shale	Los Molles	11,100	224	9,871	7,741
Neuquén	Tight	Mulichinco	4,950 - 6,400	134 - 156	2,350 - 4,900	1,300 - 3,290
Neuquén	Tight	Punta Rosada	9,500 - 1,2650	205 - 250	4,400 - 10,800	3,630 - 8,000
Neuquén	Tight	Lajas	12,900	255	10,275	9,491
GSJ	Tight	D-129	9,700 - 10,000	210 - 230	5,060 - 7,100	3,900 - 4,500
GSJ	Shale	D-129	11,680	235	8,380	5,267
Cuyo	Shale	Cacheuta	11,190	256	10,210	8,173
Cuyo	Tight	Potrerillo	11,870	268	12,188	9,050

Table 1 – Summary of Argentinian reservoir conditions.

- Closure stress on proppant
  = between 1,000 to 5,000 psi.

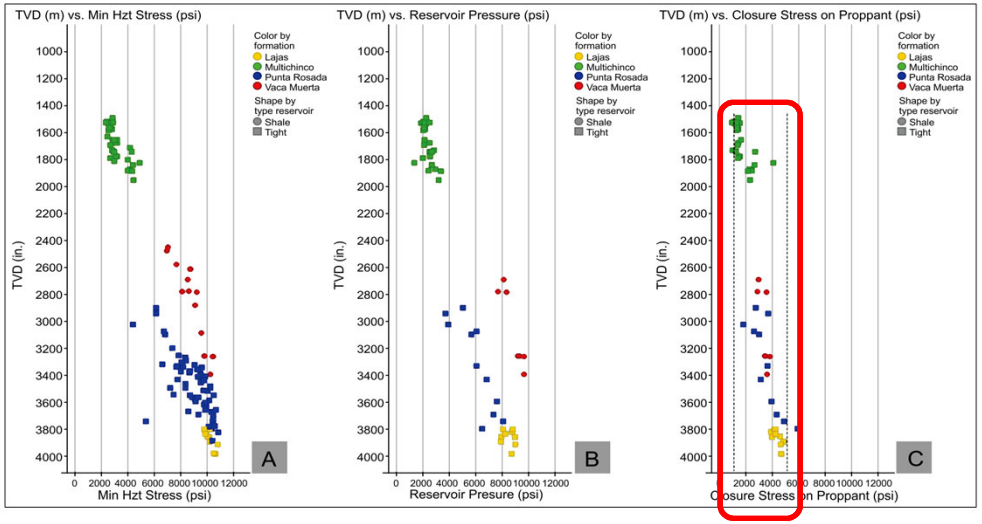


Fig. 2—(a) Minimum horizontal stress vs. depth; (b) Reservoir pressure vs. depth; (c) Closure Stress on proppant vs. depth for unconventional reservoirs in Neuquén Basin.

Proppant Type and Stimulation

Argentina Shale Fms.

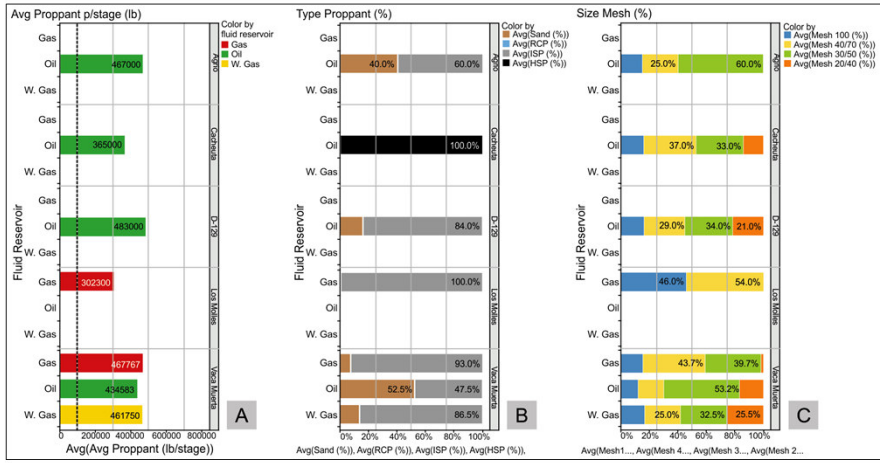


Fig. 3—(a) Average proppant volume per stage (lb); (b) Percentage according to the type of proppant; (c) Percentage of mesh size used for several Argentina shale plays.

Vaca Muerta Fm.

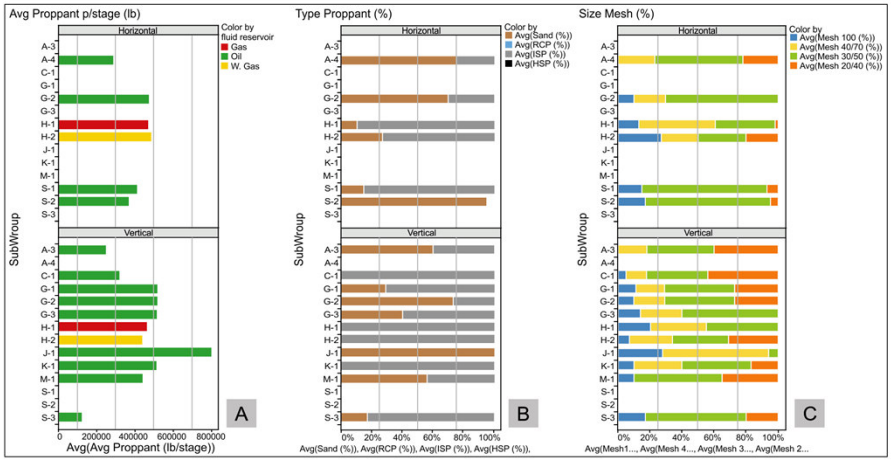


Fig. 4—(a) Average proppant volume per stage (lb); (b) Percentage according to the type of proppant; (c) Percentage according to the mesh size (Vaca Muerta formation).

- *450,000 lbm Avg Stage*
- *Type of proppant (white sand & ISP)*
- *4 mesh type*

SubGroup Well	Hztal section	No. of Stimulations	Avg Prop per Stage	Total Well Prop used
A4	1,600 ft	8 Stages	300,000 lbm	2.40 million lbm
G2	5,600 ft	17 Stages	490,000 lbm	8.30 million lbm
H1 & H2	4,600 ft	11 Stages	475,000 lbm	5.22 million lbm
S1 & S2	4,900 ft	20 Stages	370,000 lbm	7.42 million lbm

Table 2—Summary of horizontal completions in Vaca Muerta formations.

Proppant Type and Stimulation

Argentina Tight Fms.

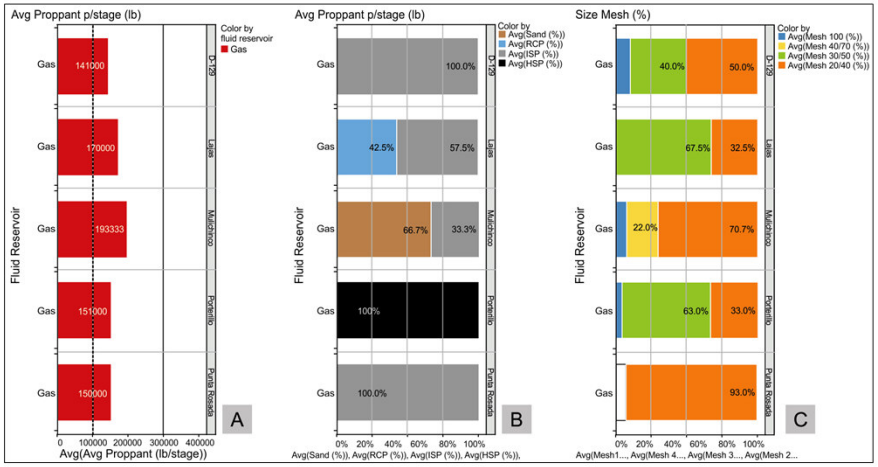


Fig. 5—(a) Average proppant volume per stage (lb); (b) Percentage according the type of proppant; (c) Percentage of mesh sized used for several Argentina tight formations.

Neuquén Tight Fms.

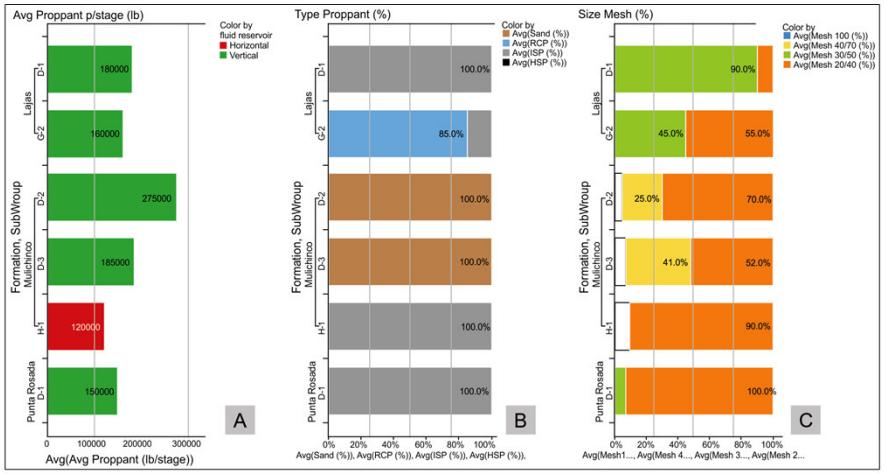


Fig. 6—(a) Average proppant volume per stage (lbm); (b) Percentage according to the type of proppant; (c) Percentage according to the mesh size used.

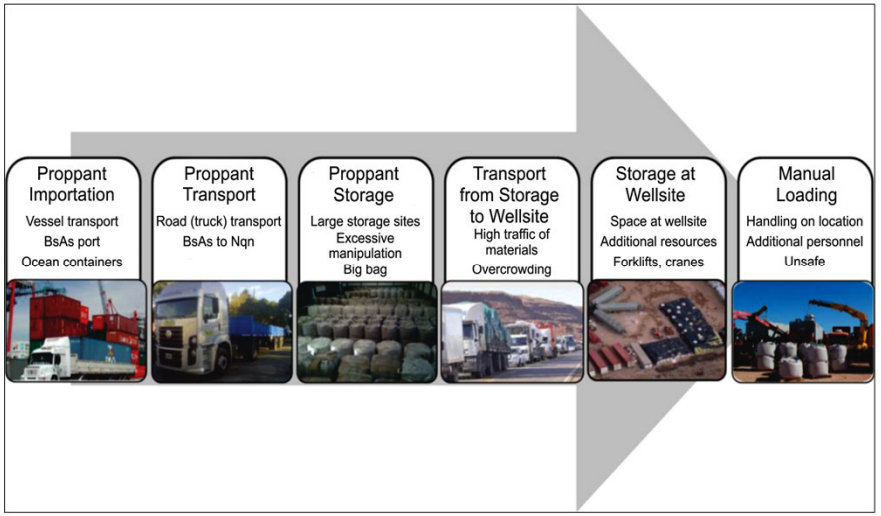
- *150,000 lbm Avg Stage*
- *Type of proppant (white sand & ISP)*
- *2 mesh type*

SubGroup Well	Type of Well	Formations	No. of Stimulations	Total Well Prop
D1	Vertical	Lajas & Punta Rosada	2 - 10 Stages	1.8 million lbm
G2	Vertical	Lajas	9 Stages	1.45 million lbm
D2	Vertical	Mulichinco	2 Stages	825,000 lbm
D3	Vertical	Mulichinco	3 Stages	555,000 lbm
H1	Horizontal	Mulichinco	15 Stages	1.8 million lbm

Table 3—Summary of completions in tight formations.

Logistic and Proppant Supply Chain

Traditional



New Model

Logistic and Supply Chain

New Model for Proppant supply (2011 to 2015)

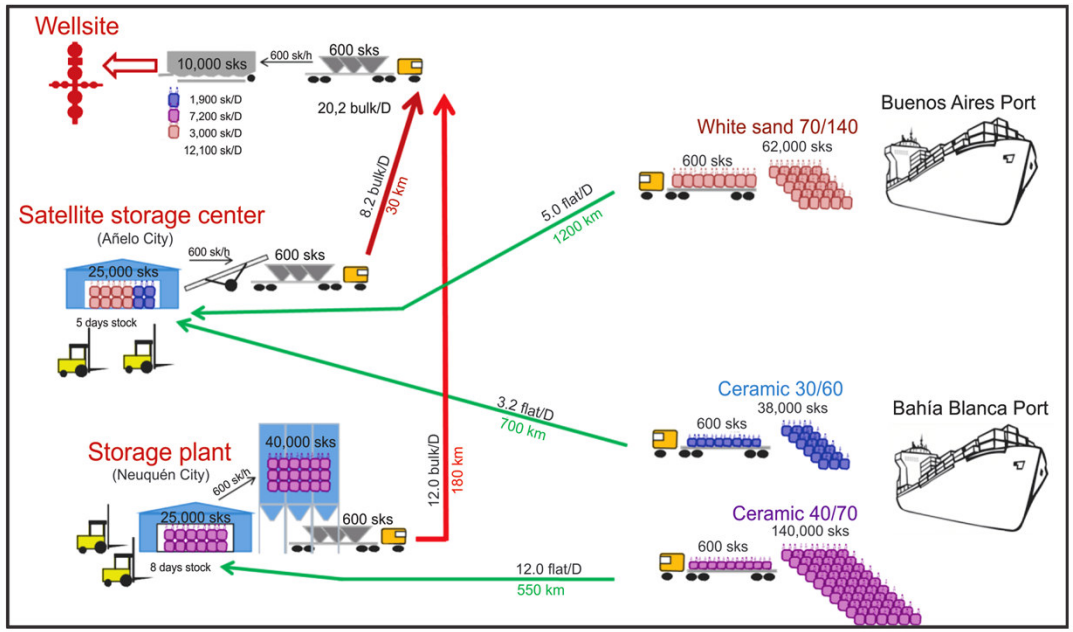
- First Part – *New port, transport (breakbulk), flatbed or rail*
- Second Part – *change big bag to bulk concept, plant or satellite center, storage capacity*
- Third Part – *proppant transport plant to wellsite (bulk transport,loading an wellsite storage capacity)*

- Storage Plant
- Satellite Storage Center
- Bulk Tansport Units
- Storage Units at wellsite

Logistic and Supply Chain

Case History – Two location Pads with 6 Horizontals wells

- 64 Fracturing Stages
- 24 MM lbm propant
  - 70/140 = 6.2 MM lbm,
  - 40/70 = 14 MM lbm
  - 30/60 = 3.8 MM lbm
- 1.21 MM lbm proppant a day



Considerations: *Proppant Suppliers – Storage Center and Delivery*

Logistic and Proppant Supply Chain

Traditional ***New Model***

Improvement

Wellsite Storage capacity

Delivery time

Safety operation

Location space

Laboratory Test for Local White Sand

- Evaluation local sand
  - *Kothamasu (2012), Kamat (2011), Peñaranda (2014)*
- API/ISO Standards
  - *sieve analysis, crush resistance, sphericity and roundness, acid solubility, and turbidity*
- Argentina local white sand *(13 samples)*

Proppant Size	GS	LS-1	LS-2	LS-3	LS-4	LS-5	LS-6
40/70	X	X	X	X		X	X
30/50 & 30/70*	X	X	X	X	X	X*	
20/40	X		X	X	X		

Laboratory Test for Local White Sand

Sieve Analysis

Proppant size	Sieve size	GS	LS-1	LS-2	LS-3	LS-4	LS-5	LS-6
40/70	30	0.0	0.0	0.07	0.0		0.01	0.02
	40-70	98.54	97.30	96.81	99.24		91.14	96.07
	100	1.00	0.19	2.96	0.36		7.65	3.85
30/50 and 30/70*	20	0.0	0.0	0.0	0.0	0.0	0.0	
	30-50/60*	98.86	99.98	86.98	99.99	99.36	96.09	
	70-100*	0.94	0.02	12.11	0.0	0.54	3.85*	
20/40	16	0.0		0.0	0.0	0.0		
	20-40	98.51		99.36	99.95	99.50		
	50	0.96		0.20	0.05	0.40		

Sphericity and Roundness

Supplier	40/70		30/50 and 30/70*		20/40	
	Sphericity	Roundness	Sphericity	Roundness	Sphericity	Roundness
GS	0.70	0.70	0.70	0.70	0.70	0.70
LS-1	0.70	0.50	0.70	0.50		
LS-2	0.70	0.50	0.70	0.50	0.70	0.50
LS-3	0.70	0.70	0.70	0.70	0.70	0.70
LS-4			0.70	0.50	0.70	0.70
LS-5	0.80	0.50	0.80*	0.60*		
LS-6	0.80	0.70				

Acid Solubility and Turbidity

Supplier	40/70		30/50 and 30/70*		20/40	
	Ac.Solubility	Turbidity	Ac.Solubility	Turbidity	Ac.Solubility	Turbidity
GS	2.3%	36	1.8%	31	1.9%	64
LS-1	4.0%	47	6.2%	65		
LS-2	10.2%	667	10.6%	68	8.2%	50
LS-3	4.8%	15	4.6%	66	6.6%	21
LS-4			5.8%	89	7.3%	89
LS-5	2.9%	445	2.6%*	340*		
LS-6	2.8%	350				

Crush Resistance

Supplier	40/70		30/50 and 30/70*		20/40	
	4 lb/ft^2	1 lb/ft^2	4 lb/ft^2	1 lb/ft^2	4 lb/ft^2	1 lb/ft^2
GS	6K - (4.67%)	6K - (6.87%)	6K - (7.07%)	6K - (8.84%)	5K - (8.96%)	5K - (9.97%)
LS-1	4K - (6.81%)	4K - (7.11%)	4K - (9.15%)	4K - (9.78%)		
LS-2	5K - (9.86%)	5K - (9.20%)	5K - (9.06%) ➡	4K - (9.11%)	4K - (8.20%)	4K - (9.83%)
LS-3	5K - (6.38%)	5K - (7.15%)	4K - (9.30%)	4K - (9.93%)	3K - (7.02%)	3K - (9.68%)
LS-4			4K - (9.95%)	4K - (9.48%)	3K - (3.20%)	3K - (6.90%)
LS-5	5K - (7.89%) ➡	4K - (8.70%)	5K* (8.89%) ➡	4K* (6.37%)		
LS-6	4K - (6.53%) ➡	3K - (9.10%)				

Discussion

- Argentina local sand are non-API/ISO.
- Improvement opportunities in the manufacturing process
  - *classification, screening, and distribution of the meshes (sieve analysis)*
  - *cleaning of the material (turbidity).*
- Nature of the deposits or the grain (quartz)
  - *roundness and acid solubility - Kamat (2011), Peñaranda (2014) observed the same*
- Crush Resistances = 1 to 2Kpsi less than GS, at 1 lbm/ft^2 is the same
- Improve crush resistance by coating - *Kamat (2011), Nguyen (2014), Stegent (2010)*

Conclusions

- Unconventional Fm. - *Closure stress on proppant (1,000 to 5,000 psi)*
- Shale
  - *3 to 4 mesh size, combine sand + ceramic, 2MMlb (Vw) to 8.5MMlb (Hw)*
- Tight
  - *2 mesh size, one type proppant (sand or ceramic), 1.45 to 1.8MMlb MultStgWell*
- New Model Proppant Supply
  - *New Port, Storage Plant, Satellite Center, Bulk transport and Storage at wellsite*
- Local sand
  - *Non-API/ISO, crush resistance (1 to 2Kpsi less than GS and low concentration)*
  - *Could be use in Unconventional reservoir*
  - *At higher clossure stress could be possible to coating the proppant*
- Cost-Effective proppant alternative is a key factors to achieving a sustainable unconventional project development.

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